A three-paper investigation of
Head Start Participants' Outcomes in Executive Functions, Reading and Math
at Kindergarten Entrance and Through the Transition to School (K-2)

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Abstract

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Three questions are explored in this dissertation. The first is whether the executive functions of Head Start participants are improved in comparison to those of children who did not attend center-based care before attending kindergarten. By matching and comparing the outcomes of a nationally representative cohort of kindergarten children (ECLS-K:2011) grouped by the type of childcare they received in the year preceding school entry, I find that Head Start participants exhibit slightly higher cognitive flexibility scores (as well as reading and math outcomes) in comparison to highly similar children who did not experience center-based care before starting school. Children who participated in Head Start demonstrate working memory skills that are not significantly different from those of closely-matched children who experienced no center-based care, but their skills in this area are slightly weaker than those of similar children who attended school-based public pre-k or other center-based care. The second question is how math content level during kindergarten affects children with different early care experiences, with focus on Head Start participants. The use of piece-wise linear growth curves to analyze children's development in working memory, cognitive flexibility, reading and math reveals that advanced math content in kindergarten does have a positive relationship with math and reading achievement for Head Start participants, but these students do not gain as much on average from this instructional approach as more advantaged groups do. More basic math content, such as counting has a negative association with growth in math for more advantaged groups of children. Finally, any increases in kindergarten growth rates resulting from math content do not appear to

persist through first and second grades. The third question asks whether there are significant differences in the trajectories of Head Start participants according to parent nativity. In analysis using piece-wise linear growth curve models to analyze Head Start (HS) participants' development in working memory, cognitive flexibility, reading and math, results indicate that HS participants with immigrant parents exhibit an additional surge in EF development in the period between the spring of kindergarten and the spring of second grade, *later* than the average kindergarten increase for all HS participants. Additionally, HS participants with immigrant parents exhibit slightly higher average growth rates in reading during kindergarten when compared to HS participants with non-immigrant parents.

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II. Acknowledgments

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III. Dedication

For my beloved, inspiring daughter, Sylvia.

IV. Preface

Because of the prevalence of large socioeconomic gaps in U.S. children's educational achievement, which are present already at school entry, it is important to examine closely the effects of early childhood interventions, including early care and education programs, that might address them. These gaps, which are driven to a great extent by disparities in parental education level, continue to widen until children are at least eleven years old (Bradbury, Corak, Waldfogel, and Washbrook, 2015).

Some of the nation's most disadvantaged children attend Head Start (HS), a program originally created in order to boost educational and health outcomes as well as to support low-income parents in a "whole-child" strategy in which cognitive stimulation through center-based care is just one aspect of a broader intervention. Attention to the program's cognitive effects has intensified in recent decades, as awareness of early gaps in children's school-readiness has gained prominence. While attendance at other center-based care programs generally yields stronger cognitive outcomes even for similarly disadvantaged children, HS participants emerge with small advantages in both reading and math outcomes when compared to closely matched children who are cared for by their parents or receive only informal care from relatives or non-relatives. The advantages they gain are smaller in comparison to those seen for children who attend other types of center-based care.

While most research into cognitive outcomes investigates reading and math scores, executive functions (EFs), in particular working memory and cognitive flexibility skills, are also acutely relevant, especially for younger children. These EF measures, also strongly tied to parents' education levels (Conway, Waldfogel, and Wang, 2018), develop from very early in childhood and play a critical role in children's early achievement in schools. Deficits in these measures at kindergarten entrance predict later difficulties in math and reading (Morgan, Li, Farkas, Cook, Pun, Hillemeier, 2017). Working memory strongly predicts later academic achievement (Duncan and Nguyen, 2017), while cognitive flexibility is especially critical for important aspects of learning like reading fluency, both for readers in the earliest grades (Cartwright, Marshall, Huemer, and Payne, 2019).

The first paper of this investigation extends the framework of separately comparing HS participants to children who attended four alternative care types, in an examination of their EF skills (measured at kindergarten entrance). At the same time, I also analyze reading and math scores in this framework, along with several measures of learning-related and social-emotional behaviors by teachers.

More recently, research in early achievement has begun to focus on the transitional years, as children begin kindergarten and move through the earliest years of school. For disadvantaged children, in particular, outcomes typically converge in this period; some theorize that children who did not attend programs designed to boost disadvantaged children's preparedness for school simply "catch up" to those who did attend HS or other center-based care, thanks in part to efforts by teachers to address gaps for those children who are most at-risk for learning difficulties (Ansari and Pianta, 2018). This "catch up," or convergence, does not erase gaps in achievement overall, but research into growth trajectories offers valuable information in several respects. Some research in this area focuses primarily on efforts to equalize opportunities for the most disadvantaged children, by studying measures that are intended to ease school transitions for children who did not attend center-based care; these children may benefit from special measures to acclimate to the school environment, such as early home visits by kindergarten teachers. Other inquiries highlight shifts in classroom instructional practices, such as aligning content appropriately, that could be considered “low-cost interventions” and potentially benefit most all students. One such set of practices involves aligning kindergarten mathematics content in adjustment with the great majority of kindergarteners today, who arrive at school knowing a great deal about basic math topics (such as counting, and identifying shapes). Currently, teachers frequently spend most instructional time in the classroom for all children on these basic skills. Recent analyses find, however, that on average, basic math content is associated with lower math achievement during kindergarten, and more advanced content (in lessons on addition and subtraction, for example) is associated with greater gains. Current research into math content level exposure in kindergarten has included only very minimal exploration of differential associations by subgroup, and no study of the persistence of any gains or positive associations.

The second paper here will extend the early care type framework to compare growth rates in math, reading, working memory, and cognitive flexibility through the first three years of formal schooling (through second grade) for HS participants in comparison with the four other groups of children defined by early care type. To see when and whether achievement rates converge for these groups of children, especially disadvantaged children, may inform ideas about the effectiveness of early interventions, as well as about instructional practices during the transitional period into school. Additionally, I examine whether associations for children from each care type are consistent with the literature on kindergarten mathematics content, with focus on the possibility of differential associations for HS participants, and I examine whether for each group any positive associations appear to persist through the first and second grades. Knowing that math and reading learning are closely associated in this period, and that early mathematics interventions have been known to improve EF skills, I test associations not only for math but for reading, working memory, and cognitive flexibility.

In the third paper, I use the framework of the second paper in order to investigate how growth rates on those four outcomes might differ, among HS participants, for the children of immigrant parents, in contrast to the children of non-immigrant parents. Numbers of U.S. children of immigrant parents have grown rapidly in recent decades and now form a high-percentage of the country's low-income children. The achievement of the children of low-income immigrant parents has been an important research focus in some education literature, with such children sometimes exhibiting unusual trajectories (Reardon and Galindo, 2009) and atypical advantages in some EFs (Hartanto, Toh, and Yang, 2019). The HS program has been shown to produce unusually persistent vocabulary gains specifically for Spanish-speaking children (Domina, Bitler, and Hoynes, 2014), and the ECLS-K provides a sample, with EF outcomes, with which to examine growth rates across parent nativity and with reference to initial levels and growth rates in both working memory and cognitive flexibility. Additionally, I am interested in learning whether there are significant differences in how the outcomes of HS participants who are children of immigrants are affected by exposure to levels of math content during kindergarten. While having no strong hypothesis, I suspect that since some children of immigrants exhibit persistent strong trajectories especially in math, more strongly positive associations might emerge for exposure to more advanced math content. Again, a better understanding of such patterns could inform educators and policymakers on a range of important issues, from addressing deficits before school to defining policies on early assessment and teaching focus during kindergarten.

IV. Paper 1: Does Head Start Participation Support Executive Functioning at Kindergarten Entrance?

Introduction

Head Start (HS) is a federal program designed to boost the educational opportunities and health outcomes of the most disadvantaged three- and four-year-old children in the United States, with annual federal spending at more than $8.2 billion (USDHHS-ACF, 2018). The program's effectiveness has been under study, and evaluations have yielded widely varying estimations of its impacts. While many studies including the recent randomized controlled trial have found that HS's effects fade out over time, more recent research focusing on HS participation *for children who would otherwise have remained at home with parents or other relatives* has demonstrated significant cognitive effects that persist into early elementary school (Shager, Schindler, Magnuson, Duncan, Yoshikawa and Hart, 2013; Zhai, Brooks-Gunn, and Waldfogel, 2014; Walters, 2015). Such evidence is particularly significant because of the potential for early care and education (ECE) to reduce early achievement gaps (Magnuson and Duncan, 2016), and because low-income children remain the least likely to receive ECE services (Magnuson and Shager, 2010).

No study has yet used the analytic framework of alternative care types in order to examine the effect of HS on children's executive functions (EFs). However, EF is important to study because low levels of EF skills at kindergarten entry predict learning difficulties in subsequent years of school (Morgan, Li, Farkas, Cook, Pun, Hillemeier, 2017). This relationship exists over and above low initial levels of achievement or demographic and socioeconomic characteristics, though low EF skills are strongly predicted by low income-to-needs (Hackman, Gallop, Evans, and Farah, 2015). While cognitive scientists and educators continue to learn how the development of EFs supports and relates to children's academic growth, it seems certain that weak EFs can be used as diagnostic markers prompting early intervention (Diamond, 2013; Morgan, et al., 2017). It has also been proposed that ECE programs that support EF development can play a critical role in decreasing early achievement gaps for low-income children and boosting their eventual life outcomes (Diamond and Lee, 2011), although evidence also suggests limited effectiveness for training that targets EFs specifically (Melby-Lervag and Hulme, 2013).

In investigating whether HS supports EFs in children as they enter formal schooling, I emphasize comparison of program participants to children who remained at home with parents or received care in an informal setting from relatives or non-relatives rather than attending other center-based care, since similar comparisons have demonstrated evidence of positive effects in cognitive and other domains (Lee, Zhai, Brooks-Gunn, Han, and Waldfogel, 2014; Lee, Zhai, Han, Broks-Gunn, and Waldfogel, 2013; Shager, Schindler, Magnuson, Duncan, Yoshikawa, and Hart, 2013). I find positive significant HS effects on children's cognitive flexibility at kindergarten entry for children who in the absence of the program would not have received center-based care, but I also find that the program has no effect on children's working memory in comparisons with this comparison group. I do find negative HS effects on working memory and several other outcomes in comparisons with closely-matched children who attended school-based public pre-k or other center-based programs. I discuss results with reference to scholarship on early EF development and its relationship to achievement and other important outcomes. As part of my investigation, in subsequent papers, I shall a) explore the growth in EFs and other outcomes for HS participants in their early grade school years; and b) investigate how school characteristics, including those associated with specific school practices, may provide additive support to EF development after program participation, particularly with respect to particularly disadvantaged subgroups of children.

Literature Review

1. The Head Start program: Evaluative Research

Creation of Head Start and increases in ECE participation

A key program originating in 1965 as part of War on Poverty, Head Start (HS) was created to narrow the socioeconomic gap in children's early life experiences produced by dramatically unequal levels of family resources. From the program's earliest years, HS centers were required to ensure that at least 90% of participating children were families living below the poverty line. In addition to providing center-based care featuring educational and medical services, the program has consistently aimed to increase parents' awareness of their influence on their children's development and to address children's social and emotional well-being (Pizzo and Tufankjian, 2004). HS was also designed to support those with specific deficits; each HS center must reserve 10% of its places for children with diagnosed disabilities (as defined under the Individuals with Disabilities Education Act, or IDEA).

The decades following the program's founding coincided with a substantial increase in employment rates among U.S. mothers of young children. As a result, greater numbers of children began to receive early care and education (ECE) services when their mothers were not available to care for them during work hours; more children in all income groups began to attend center-based care (Chaudry, Morrissey, Weiland, Yoshikawa, 2017). A particularly large increase in maternal employment among low-income families led to increasing enrollment in HS programs as well as the creation of alternatives to HS that more fully supported the schedules of working mothers (Chafel and Sugioka, 2004; Waldfogel, 2006). Federal laws in the 1980s first expanded funding for childcare in low-income families and created the Child Care Development Block Grants (CCDBG). These grants supported low-income families through discretionary funding for subsidized care at locally maintained centers; the care varied widely in quality, but freed low-income parents to begin work or become trained to work. Further changes to federal law in the mid-1990s made maternal employment a requirement for the receipt of welfare benefits, concurrently removing childcare funding as a federal entitlement and transferring the administration of subsidy funds to the state level (Currie, 2006).

Such changes in demand and funding practices produced waitlists for childcare programs where parents used subsidized care, but they also encouraged numerous states and municipalities to create public pre-kindergarten (or “pre-K”) programs, several of which have demonstrated boosts to children’s school-readiness, particularly in cognitive domains (Chaudry, 2017). By 2009, the year that is the focus of data used in this work, such programs were funded by state and local money in 38 states (Barnett, Epstein, Carolan, Fitzgerald, Ackerman, and Freedman, 2010). More broadly, by that year more than one-third of all four-year-old children from low-income families in the U.S. participated in at least one publicly-funded center-based care program, whether public pre-K, HS, or other center-based care supported by childcare subsidies (Barnett et al., 2010; U.S. Government Accountability Office, 2016).

Early ECE scholarship and the HSIS

Along with the proliferation of early care choices for low-income parents, advances in developmental psychology and related fields raised awareness across several disciplines of the importance of early childhood experiences in fostering neural growth and related capacities in preparation for schooling (Heckman, 2007). Interest in evaluating the efficacy of HS and other programs grew naturally out of these advances, especially in light of an early impact study administered in 1969 suggesting that the program's benefits did not in fact persist in the years after children completed it (Besharov, Germanis, Higney, and Call, 2011). Meanwhile, decades-long studies of "model" ECE interventions, most notably the Perry Preschool Project and the Abecedarian Program, publicized long-term boosts in the cognitive, social, behavioral, and economic outcomes of participants that were truly outstanding (Schweinhart, Barnes, and Weikart, 1993). Some critics queried whether HS, in contrast to the model programs, was doing enough for the children it served; others pointed out that the comparison was unrealistic, since HS received lower per-child funds from federal sources and was locally administered and implemented across many regions, in contrast to the carefully-managed model interventions (Powell, 2004; Currie, 2006).

At the same time, there was a growing awareness that HS did not appear to impact all children with equal effectiveness (Currie and Thomas, 1993; Currie and Thomas, 1999). Some researchers described a shifting "counterfactual environment" of care options and suggested that it was unfair to evaluate Head Start's effects without consideration of the varied ECE options for low-income families (Phillips and White, 2004). Scholars began to estimate the *relative* effectiveness of HS, pre-K, and other ECE programs while attempting to adjust for characteristics that accounted for both disadvantage level and selection. They investigated a broad range of outcomes, including cognitive scores, social behaviors, general health outcomes, obesity, parenting behaviors, and rates of child maltreatment, although children's preparation for academic engagement in the early school years remained a prime focus of this research.

In the results of some comparative studies, pre-K programs frequently appeared to produce substantially greater cognitive benefits for children than HS (Magnuson, Meyers, Ruhm, and Waldfogel, 2004; Henry, Gordon, and Rickman, 2006). At the same time, more researchers began to consider more deeply than ever the complexities of selection bias and its effect on evaluation, particularly since the families of HS participants were especially disadvantaged and, in contrast, pre-K often served more heterogenous groups of children. Additionally, the question of whether positive HS effects, particularly in cognitive domains, persisted into the school years after children attended the program became more central (Barnett, 2004). Alongside these concerns regarding research into the effectiveness of HS, government stakeholders became concerned by the program's relatively high per-child costs (Powell, 2004). In 1998, the federal government mandated that evaluation of the program be conducted using a stringent "experimental" framework. This mandate required a randomized, nationally-representative study of the program's effects on a broad range of outcomes, including health, dental, parenting, social-emotional and cognitive measures, with additional measurement of effects for subgroups of particularly disadvantaged children (USDHHS, 2005). The resulting National Head Start Impact Study (NHSIS), which today remains the only randomized evaluation of the program, followed more than 4,500 three- and four-year-olds who participated in the program across 383 centers in 23 states beginning in the fall of 2002 and continuing through third grade.

While the NHSIS did not examine EF, it did evaluate cognitive scores along with several measures of social and emotional development. An interim report found generally larger cognitive effects for three-year-old attendees than for four-year-olds, with the largest for pre-reading skills. With respect to outcomes in social-emotional development they noted positive effects for three-year-olds, with additional effects only for four-year-olds who were English-speaking. The NHSIS reported no effect, positive or negative, on parent-reported social skills or positive approaches to learning for any subgroups (USDHHS, 2005). In particular, researchers noted that the lack of any significant reduction in problem behaviors by participants as reported by the Study was inconsistent with the program's stated focus on the "whole child." Others cited the program's costs as unacceptable particularly in light of emerging evidence of some public pre-k programs' success in improving children's cognitive abilities (Besharov and Higney, 2007). In 2010, a second NHSIS report noted "few statistically significant differences in outcomes at the end of 1st grade" following "scattered" positive effects on certain subgroups, such as children from high-risk households (USDHHS, 2010), and a final report in 2012 found that almost no positive effects remained in evidence by the time the HS participants reached third grade (USDHHS, 2012).

Research in response to the NHSIS

The NHSIS results concerned researchers who compared Head Start's outcomes to those from the "model" Perry Preschool and Abecedarian Project programs, which were estimated to generate lifetime benefits to society as high as ten times the originals cost of the programs (Barnett, 2011). Of course, long-term outcomes had not been evaluated using the HSIS sample, while earlier studies implementing quasi-experimental methods with observational data had suggested positive long-term outcomes for HS participants (Garces, Thomas, and Currie, 2002; Ludwig and Philips, 2008; Deming, 2009). Some pointed out that it was inherently unfair to expect "miraculous" results from a scaled-up program serving millions of children around the country supported by staff following local guidelines and leadership, resulting in varied practices. More recently, as comparisons of the HSIS to some pre-K programs that were generating strong cognitive impacts were published, it was underscored that HS participants were means-tested and generally quite disadvantaged, while children attending pre-K were growing up in families of more varied backgrounds and thus entered the programs with higher average cognitive abilities (Phillips, Lipsey, Dodge, Haskins, Bassok, Burchinal, Duncan, Dynarski, Magnuson, and Weiland, 2017). Additionally, because of its original goals, HS expended program resources on general health and parenting/family outcomes as well as children's cognitive growth, while pre-K programs generally focused all funds on preparing children to learn in school.

In answer to these concerns, researchers continued investigating long-term effects, by examining program variation, selection issues and various data sources. In re-assessment of the interim NHSIS data, Ludwig and Philips (2008) considered both short- and long-term gains for children attending HS, with particular attention to whether children who were assigned to the program actually participated in it. Re-calculating the Study's findings to produce treatment-on-the-treated (ToT or ATT) effects rather than intent-to-treat (ITT) effects[1], they found larger, significant cognitive short-term effects for HS participants. Critically, they extrapolated these results into a cost-benefit analysis of long-term HS gains, noting that an ECE program *can* achieve long-term benefits when short-term effects are only small (.15 or .2 SD) in size; their ToT estimation of cognitive effects for HS meets that standard.

Deming (2009) investigated short- and long-term effects of HS with NSLY data, tracking children who attended the program between 1984 and 1990 and were measured through 2004, implementing within-family differences in program participation to control for family and parenting characteristics that were unobserved in the data and could bias results if not accounted for. Deming also created three summary indices of young adult outcomes (to counter the threat of multiple inference in leveraging the NLSY's generous number of outcome measures): one

[1] In the estimation of effects presented in the NHSIS reports, calculations were based on the difference-of-means for the group of children who were assigned to the treatment (of Head Start participation) and the group who were assigned to control status (non-participation), without regard to adherence or attrition. This method, commonly known as Intent-to-Treat estimation (ITT), is frequently used in policy analysis requiring knowledge relating to effects as related to the "intention to treat" individuals, as originally assigned to intervention.

measure for test scores, another measure of school-age outcomes like school retention and diagnosis of learning disability, and an index comprised of six long-term outcomes. The results for children early in their lives included an initial test score gain of .15 SD that decreased to approximately .075 SD by ages 11-14. Deming noted that this decline in test scores was especially strong for African-American children and very disadvantaged children, yet these children experienced the greatest positive effects of HS in *long-term* outcomes, including self-reported health status, rates of high school graduation and college attendance, as well as reduced crime involvement and teen parenthood. In conclusion, the author suggested that the largest returns on social investment in early education can occur with modest initial cognitive gains, echoing Ludwig and Philips (2008).

Other research explored and exploited variation in program characteristics, implementation, and expenditures to uncover heterogeneous effects while exploring the “black box” of what *does* work about HS. Currie and Neidell (2007) evaluated short-term effects by exploiting differences in program expenditure levels. Using microdata from the National Longitudinal Study of Youth (NLSY) (n=4,468), they investigated whether higher spending on HS predicted improved outcomes, by using an interaction term between each child’s HS participation status and the expenditure per child on the program in the county where the child lived at age four. In places where HS funding was greater, children who attended the program had significantly improved reading and vocabulary scores, as well as scores on behavioral measures and schooling outcomes such as retention and graduation. Additionally, these researchers determined that children in HS programs that dedicated greater resources to child-specific expenditures on education and health were less likely to experience grade retention and had fewer behavior problems in contrast to children who attended programs investing smaller amounts in child-specific spending and more in parent-focused services or administrative expenditures. More recently, Walters (2015) found considerable variation in effects among HS centers by center characteristics; those centers offering full-day care and parental services produced greater cognitive gains for children.

The importance of alternative care experienced by the control group

The HSIS compared children randomly assigned to HS to all children in the study who were not assigned to any program, yet these "counterfactual" children attended a variety of arrangements, based on availability, cost, and parents' preferences. The varied quality of these alternative arrangements has led to comparison of the effectiveness of HS against other programs; a subsequent meta-analyses of evaluative studies of HS impacts has demonstrated that effect sizes were more larger and more likely to be positive/significant when control children did not attend any form of center-based ECE and and received early care from only parents and/or relatives (Shager, Schindler, Magnuson, Duncan, Yoshikawa, and Hart, 2013). In fact, there is considerable evidence that the effects of HS depend on the alternative form of care experienced by the counterfactual group to which program participants are compared. Studies using data from the Fragile Families and Child Wellbeing Study and the Early Childhood Longitudinal Study–Birth Cohort have found that HS participants scored significantly lower on cognitive assessments than very similar children who had attended pre-K (Zhai, Brooks-Gunn, and Waldfogel, 2011; Lee, Zhai, Brooks-Gunn, Han, and Waldfogel, 2014). In contrast, in comparison with similar children who receive only care from their parents and families, those who attended HS then achieved higher scores on cognitive assessments, enjoyed superior health outcomes, and received better scores on other measures (Lee, Zhai, Han, Brooks-Gunn, and Waldfogel, 2013; Lee, Zhai, Brooks-Gunn, Han, and Waldfogel, 2014). A re-analysis of the HSIS data with focus on childcare arrangements among the control sample found that in comparison with children who experienced parental or informal care by relatives and non-relatives, Head Start participants had higher cognitive and parent-rated social-emotional assessments (Zhai, Brooks-Gunn, and Waldfogel, 2014).

Recently, researchers providing re-analysis of the NHSIS data have successfully challenged the final report's conclusion that positive effects were largely non-persistent in cognitive domains. Zhai, Brooks-Gunn and Waldfogel (2014) found that positive effects on several cognitive outcomes persisted into first grade for HS participants when compared to children in parental-only care at age four. Kline and Walters (2016) re-examined the HSIS test scores by implementing interactions of families' household characteristics and experimental status to find that HS attendance produced cognitive gains through first grade for children who were likely to remain at home with their parents in the absence of the program, and even larger gains among children from families whose unobserved characteristics suggest that they were less likely to select HS. Feller, Grindal, Miratrix and Page (2016) similarly leveraged HSIS families' compliance status in a stratification strategy using interactions by household covariates in a multilevel model, finding "modest" positive impacts through first grade on children who would, in the absence of the experiment, not have attended any form of center-based care.

Convergence of effects, and the importance of continued educational investment

Understanding the apparent non-persistence of HS effects, originally seen as "fade-out," is critical to policy consideration (Gibbs, Ludwig and Miller, 2011). As part of that understanding, it is important to note that such non-persistent effects are not limited to HS; some have found that the positive effects of pre-K participation can decline or disappear entirely, for some subgroups or for all children, in early grade school (Hill, Gormley, and Adelstein, 2015; Lipsey, Farran, and Durkin 2018). Further, the complexities around the issue of non-persistence have led some re-frame it as a "convergence" of outcomes among children in the years after their ECE experiences, rather than as a failure or "fade-out" of early gains (Barnett, 2011). One explanation of convergence points to the poor quality of schools that disadvantaged participants typically attend after the preschool years, so that the achievement level of children who attended center-based programs drops to the level of non-participants during their early schooling (Currie and Thomas, 1998). Alternatively, Barnett (2011) suggests "catch-up" as a more apt description than "fade-out" of program effects, underscoring that directed resources in public schools may sufficiently help disadvantaged children who did not attend HS (or another preschool program) to help them achieve as well as those who did. Even the HSIS findings support this hypothesis, since many of the "control children" in the study were later retained in a grade for a year or attended special education services at schools. The record of such later interventions by schools suggest that in fact, some children who did not attend HS did subsequently receive help in school to boost their achievement levels closer to those of children who received the earlier advantage of ECE attendance, supporting the "catch-up" hypothesis. Additionally, non-participants are most likely stimulated by sharing classrooms with other children who did receive the benefits of high-quality ECE programs, so that program investment is gradually distributed throughout cohorts and effectively shared with non-participants to a significant degree (Neidell and Waldfogel, 2010). The effective efforts at remediation by some schools and the positive "spillover" peer effects could combine to contribute to what looks like "fade-out" of positive effects for participants; again, this dynamic is more accurately framed as "catch-up" or "transfer of learning" for the non-participants; some posit that such transfer should in fact be fostered in order to optimize program investments (Kang, Duncan, Clements, Sarama, and Bailey, 2018).

Newer examination of the persistence of preschool effects finds that, for children who do experience the benefits of ECE (whether HS, pre-K or other center-based program), subsequent school experiences of sufficiently high quality are required to sustain those benefits (Zhai, Raver and Jones, 2012; Ansari and Pianta, 2018). Continued investment in opportunities can make all of the difference in terms of long-term outcomes; even where persistent ECE effects on achievement through middle school have been documented, those gains are heterogenous by subgroups, quite possibly because of the quality of subsequent learning environments (Gormley, Phillips, and Anderson, 2017). An examination of publicly available data (PSID) suggests that HS participants who afterward attend schools where public education expenditures have increased receive an interactive advantage from having received both kinds of support (HS followed by higher-quality public schools), yielding improved outcomes over those who experience either support alone; such individuals experienced consequent decreases in poverty and incarceration in adulthood and increases in their completed years of schooling and adult wages (Johnson and Jackson, 2017).

Further, the awareness of continued challenges faced by disadvantaged children once they leave ECE programs has led to efforts in support of adequate “transition practices” into kindergarten. Such practices vary widely, and can be universal or targeted in support of more challenged students; they can range from newsletters home, parent orientations, and open houses to having children either visit the teacher in the classroom before the start of school or attend a special instructional session during summer (Curbey et al., 2018). Transition practices have been shown to have the largest benefits for the most disadvantaged students (Schulting, Malone and Dodge, 2005), yet schools serving more disadvantaged students employ fewer kindergarten transition practices on average (Little, Cohen-Vogel, and Curran, 2016).

Another point of concern is whether children who attended pre-k or other high-quality ECE programs garner less attention and instructional time from teachers. Teachers have been found, in some settings, to focus resources on students most in need, i.e., those who did not attend pre-k and may enter school with remedial needs (Ansari and Purtell, 2018). However, for ECE participants, high-quality instruction that acknowledges some students' mastery and continues to provide them with new content leads to persistent learning impacts (Clements, Sarama, Wolfe and Spitler, 2013). In keeping with the idea of "productive continuity," some recommend broader-based strategies for the years both before and after kindergarten, such as implementing appropriate math curriculum throughout the first years of school (Clements Sarama and Geremeroth, 2016). Other research supports the alignment of instructional content, support, and pedagogical approaches across early care and school experiences (Stipek, Clements, Coburn, Franke, Farran, 2017). Investigation is underway into the persistence of ECE effects' relationship to elementary school "curriculum upgrades" and teachers' differentiation of instruction for children who did and did not attend pre-K or other ECE programs (Gormley, Phillips, and Anderson 2017). That the first few years of formal schooling provide appropriate cognitive stimulation, for those who have attended ECE as well as those who did not and are most in need of "catch-up," is of particular concern (Claessen, Engels, Curran, 2014; Brooks-Gunn, Markman-Pithers, Rouse, 2016; Ansari and Pianta, 2018).

2. Executive Functions as Outcomes of Early Childhood Education Programs

The development of executive functions in early childhood and beyond

Executive functions (EFs) form a set of volitional (rather than automatic or instinctual) processes that enable the accomplishment of goals (Blair and Razza, 2007; Diamond, 2013). Their development is supported by parents and other caregivers beginning in infancy and early childhood, and this foundational mechanism continues to function, throughout middle childhood and through adolescence, in tandem with children's learning environments outside the home (Bernier, Carlson, and Whipple, 2010; Bernier, Carlson, Deschênes, and Matte-Gagné, 2012; Conway and Stifter, 2012; Blair, Raver, and Berry, 2014; Zelazo and Muller, 2002). Preschool is the crucial time of emergence for three distinct, core EFs that enable children to resolve conflicts and integrate complexity: inhibitory control, working memory, and cognitive flexibility (Zelazo and Frye, 1998; Zelazo and Muller, 2002; Diamond, 2006). These core EFs are closely interconnected and overlap in their engagement and evolution, while their developmental trajectories are distinct from one another. Researchers study them either as separate measures or as a unitary construct in order to examine different aspects of cognitive growth and learning (Garon Bryson and Smith, 2008).

The most fundamental of the core EFs, inhibitory control (IC) is typically measured using tasks during which children must maintain focused attention in order to stop themselves from making their "automatic" response to a cue, as for example in the Delay of Gratification (or marshmallow) paradigm (Mischel, 1974). Working memory (WM) develops initially as the ability to hold information in mind and evolves to enable operations using the information, and is also referred to as "updating." It is tested in children as young as two or three by requiring them, for example, to repeat a string or "span" of numbers, letters or words, and as children grow older by asking them to reverse the order of items before repetition (as in the Numbers Reversed task) or otherwise asking children to hold information in mind and manipulate it (Gathercole, 1998; Brocki and Bohlin, 2004). Particularly as children mature, WM covaries with children's levels of attentional control (Espy and Bull, 2005), and many tasks that measure children's developing WM require the engagement of IC as well (Diamond, 2002). Similarly, the more advanced tasks measuring IC can also tax children's attentional systems by requiring them to engage WM, as for example when they must hold a rule in mind in order to cross-match objects by category in a Stroop task (Carlson, Mandell and Williams, 2004).

Cognitive flexibility (sometimes referred to as “cognitive shifting” or just “shifting”) is a somewhat more complex EF that also develops in the early childhood. It requires the engagement of both WM and IC, and for children in late preschool or early grade school, its measurement generally involves multiple rule changes. An example of the kind of task that measures cognitive shifting is the Dimensional Card Change Sort (DCCS) task, which requires children to shift their attention from one characteristic of stimuli to another throughout trials of increasing complexity (Doebel and Zelazo, 2015). During the preschool years, children’s scores in cognitive shifting and IC can intermittently exhibit negative correlations with one another (Jones, Rothbart, and Posner, 2003), in evidence of a natural, temporary conflict at this age between attentional focus, or maintaining attention on a single rule or stimulus, and flexibility in response to changing rules or stimuli. The resolution of this conflict, around age six in most children, is a key signal of more mature executive functioning and readiness for academic learning. The integration is observable in the more advanced trials of the DCCS (Rothbart and Posner, 2001).

The three core EFs continue to develop and in fact co-develop in important ways throughout kindergarten, the early grade school years, and later. Their growth is not always colinear, as already mentioned with respect to IC and cognitive shifting, where the development of one EF can seem to compete with another for a period of time. Individual differences are ubiquitous; some children’s temporary inability to inhibit themselves from acting on their initial responses may even signal a surge of growth in their cognitive flexibility, so that their later school progress may show no deficits in academic ability. Full emergence and integration of the core EFs requires many years, and sometimes a single task that sufficiently taps certain skills over time reflects this; children’s performance on the Dots (or Hearts and Flowers) task, which requires both retrieval and updating of information that they must hold in mind, reveals that WM continues to develop at least until age 13 (Davidson, Amso, Anderson, and Diamond, 2006). Results across a range of studies demonstrate continued "fine-tuning" of both WM and IC throughout adolescence (Luna, 2009). Since cognitive flexibility relies on both of these other two core EFs, it too continues to evolve into early adulthood.

EFs' relationship to achievement and other early outcomes

Children's executive functions (EFs) are especially important in school contexts because they enable them to pay attention, follow instructions, and get along with their peers (Blair and Raver, 2015). Longitudinal investigations have established that EF skills have strong, often predictive, relationships to achievement in math and reading. Working memory has especially strong links to academic achievement throughout children's schooling. As measured in toddlers at age two, it predicts several indicators of children's school readiness at kindergarten, including teacher ratings of classroom engagement, number knowledge, and receptive vocabulary, after controlling for socioeconomic background (Fitzpatrick and Pagani, 2012). Preschoolers' scores on working memory tasks and more general EF skills predict their performance in math and reading tests at age seven (Bull, Espy, and Wiese, 2008). Recent cohort investigation has demonstrated a far stronger association for WM at kindergarten entry with third-grade math and reading achievement than for IC or cognitive shifting (Nguyen and Duncan, 2019). "Complex" executive function (a single measure comprising all three core EFs as well as higher-level EFs such as planning), when measured in children from the ages of five to seventeen, was correlated in a "domain general" way to children's achievement throughout that period of development (Best, Miller and Naglier, 2011).

Whether a straightforward causal relationship exists between early EFs and students' subsequent achievement has been questioned, particularly since many early studies of the relationship often featured small samples, cross-sectional data, or insufficient inclusion of potential confounders (Jacob and Parkinson, 2015). Evidence has emerged of a bidirectional developmental relationship between EFs and some academic abilities in the early school years, especially for math skills (Bull, Espy and Wiebe, 2008; Fuhs, Farran, Nesbitt, and Dong, 2014; Clements, Sarama, and Germeroth, 2016). Working memory, in particular, has been demonstrated to have a bidirectional relationship with mathematics through first grade (Nesbitt, Hughes, and Farran, 2019). However, in a nationally representative examination of second-graders' achievement and behavioral outcomes (internalizing and externalities) implementing prior measures of achievement, including vocabulary, find that all three core EFs positively predict reading, mathematics, and science achievement, over and above all potential confounders, including socioeconomic status, suggesting a causal relationship through which EFs contribute directly to students' learning (Morgan, Farkas, Hillemeier, Pun, and Maczuga, 2018).

Both the overlapping development of the core EFs and the changing nature of what children learn in school at different ages create complexity in the connections between academic growth and particular EFs (Monette, Bigras, and Guay, 2011; Bull and Lee, 2014). EFs play an especially critical role when particular tasks are not yet fully automated (Diamond 2013; McClelland and Cameron, 2018). For very early readers, for example, "decoding" specific words requires quite different skills in contrast to reading comprehension, which is required of older children across subjects; at older ages, therefore, cognitive flexibility generally becomes much more important. Students with difficulty in reading comprehension are likely to have low scores on all three core EFs, including cognitive shifting, resulting in "an inability to actively switch between letter-sound information and meaning of print" (Cartwright, Coppage, Lane, Singleton, Marshall, and

Bentivegna, 2017). Shifts in curriculum from one year to the next in early math instruction have been hypothesized as an explanation for a change, during kindergarten, from a bidirectional to predictive relationship for EFs with math abilities (Schmitt, Geldoff, Purpura, Duncan, and McClelland, 2017).

Similarly, deficits in children's early EF abilities frequently presage or co-occur with social-emotional difficulties, just as poor achievement and social-emotional difficulties are often linked (Duncan and Magnuson, 2013). A unitary EF construct measured across the "transition to school" from preschool onward predicts teacher assessments of both internalizing and externalizing behaviors, as well as children's self-perceptions of academic and social competencies, at age 6 (Hughes and Ensor, 2011). In nationally representative data, children's IC (as measured in kindergarten using teacher assessments) strongly predicts both internalizing and externalizing behavioral assessments by teachers in second grade (Morgan et al., 2018). It is easy to imagine that children who are able to inhibit their impulses, remember rules and facts well, and manage to shift their responses to unpredictable stimuli are also better able to navigate the challenges of staying on task, learning new material, getting along with other children and having positive interactions with teachers. For some time, researchers interested in educational disparities have given focus to the importance of social-emotional assessments and teacher ratings of children's classroom behaviors, attention skills, and "foundational abilities" alongside cognitive scores in reading and math (Duncan, Dowsett, Claessens, Magnuson, Huston, Klebanov, Pagani, Feinstein, Engel, and Brooks-Gunn, 2007; Duncan and Magnuson, 2013; Razza, Martin, and Brooks-Gunn, 2015). Teachers' assessments of kindergarteners' social and attentional skills predict math and reading achievement in sixth grade (McClelland, Acock, and Morrison, 2006). Children who are able to exhibit better behaviors in school with peers and teachers may also be able to navigate life challenges for better long-term outcomes, such as graduation and employment. EFs are thought by some to be closely related to the characteristics of “resilience” and “character” recently under study, or to the “soft skills” believed to predict long-term outcomes even more solidly, for some children, than school achievement does (Heckman and Kautz, 2013). It may be that social-behavioral skills act as a key mediator in the relationship between EFs and achievement[2] (Baptista, Osório, Martins, Verissimo, and Martins, 2016).

Study of EFs in disadvantaged children and potential remediation of EF abilities

What does seem clear from the research into EFs and children’s achievements is that very poor executive functioning in early childhood is a signal of likely academic challenges (Morgan et al., 2017). Unsurprisingly, research has established a positive and consistent relationship between children’s EF development and their families’ socioeconomic status (SES), continuing from early life through adolescence (Blair and Diamond, 2008; Hackman and Farah, 2009; Hackman, Gallop, Evans, and Farah, 2015). At school entry in particular, EFs are linked to their families’ SES (Noble, Norman, and Farah, 2005). On assessments of working memory and cognitive shifting administered at the start of kindergarten, children from households in the highest income quintile in the U.S. score approximately a full standard deviation above those from households in the lowest income quintile (Little, 2017). Especially given that children with serious deficits in working memory and cognitive flexibility at school entry are at considerable

[2] Other foundational abilities, such as early fine motor skills and visuomotor skills, are also strongly and bidirectionally related to both achievement and EFs in the early school years (McClelland and Cameron, 2018; Nesbitt, Fuchs, and Farran, 2019); a “compensatory” action of such co-development has been noted between visuomotor integration and IC in the emergence of school-readiness (Cameron, Brock, Hatfield, Cottone, Rubinstein, LoCasale-Crouch, and Grissmer, 2015).

risk for reading and math difficulties in first grade (Morgan et al., 2016), recent research has explored the means by which children's early EF abilities affect later academic outcomes and the potential benefits of early remediating interventions for EF skills (Diamond, 2013).

A clearer understanding of the mechanisms underlying the role of EFs on achievement, and even ideas about whether interventions may help subgroups of children differentially, is emerging as studies trace some key pathways with reference to disadvantaged children. While focusing on the neural development of low-income children, Blair and Raver (2012) highlight the disruption of self-regulatory growth through the impact of severe socioeconomic disadvantage on families' ability to provide consistent and nurturing care. Resulting hormonal and behavioral shifts, while initially adaptive for life in a challenging environment, can place children at serious risk by compromising EF development, leading in cases to a range of behaviors from under-engagement with peers and teachers to ADHD diagnoses to unruly and even violent behavior in schools (Blair and Raver, 2015). The attendant jeopardy for children is so great that researchers in this area support the "buffering effect" of childcare outside of the home for children in particularly high-risk homes (Berry, Blair, Ursache, Willoughby, Garrett-Peters, Vernon-Feagans, Bratsch-Hines, Roger, Granger, 2014). Particularly for these children, an early intervention with strong focus on self-regulation may be highly appropriate to offset the effects of severe stress (Blair and Diamond, 2008).

Another framework for understanding the relationship of SES and EFs in low-income children focuses less on self-regulation and more on diminished parental resources and poorer language abilities resulting from children's home environments. Examining differences in the brain functioning of two groups of kindergarteners growing up in homes of low- vs. mid-level SES, Noble, Norman, and Farah (2005) demonstrate that SES is strongly associated with both a) the brain’s language system (EF = 1.1 SD) and the executive system (EF = .68 SD). Finding that SES “did not account for any variance in EF over and above that predicted by language,” the authors suggest that language may be the primary path through which SES influences the development of EF. This study’s findings are consistent with earlier scholarship highlighting a large SES-related gap in the total spoken vocabulary arising from the very early lives in young children, with direct consequences for their cognitive growth (Hart and Risley, 1992). Compensatory pre-kindergarten programs in which teachers are coached in the use of cognition-focused curricula addressing early language deficits do seem to provide boosts in school-readiness for certain children (Weiland and Yoshikawa, 2013).

Additional research suggests a pathway involving language development with early EF development, through findings that executive control (EC) (a unitary EF construct) predicts EF task performance by preschoolers in a way that is entirely unrelated to socioeconomic variation (Clark, Chevalier, Nelson, James, Garza, Choi, and Espy, 2016). In a longitudinal examination of 388 children’s performance of EF tasks at ages 4.5 and 5.25 years, this study finds that the effect of variation in SES on EF tasks is moderated instead by “household and financial” factors. Parent’s income and educational levels differentially enable their children’s “foundational cognitive abilities” (including language, visual-spatial, and even motor skills), building competencies such as recognizing shapes and colors and vocabulary in the very early years, even before preschool. In related work, Clark, James, and Espy (2016) theorize that the cognitive enrichment that children receive in more prosperous families provides critical priming of their “early perceptual processing” and thusly prepares them for EF challenges in preschool. In contrast, children from lower-income homes, even in the absence of severe deprivation, do not receive similar priming and thus perform at lower levels at early ages. This theory is additionally supported by a recent finding that, among the components of SES, parent education accounts for the greatest variation in discrepancies in kindergarteners' cognitive flexibility and working memory skills (Conway, Waldfogel, and Wang, 2018).

It seems increasingly clear that what children experience in schools and classrooms can either confer compensatory benefits for those who begin school with learning deficits, or work against them. In work that explores bidirectional development, or co-development, occurring in very young children's cognitive abilities, evidence suggests that high-quality math instruction for very young children can extend both math knowledge and "enable and exercise" EF development, possibly more reliably than interventions targeting only EFs (Clements, Sarama, Geremoth, 2016). Recent exploration of schools' compositional effects on EF growth in kindergarten, first and second grades suggests high-SES schools contribute the largest monthly increase in EF skills growth, while schools with high enrollment levels of Black and Hispanic students (and presumably lower levels of funding) influence average EF growth in a negative direction (Ready and Reid, 2019).

Purpose of This Paper

That Head Start's effects on children's outcomes are both positive and persistent for those children who would have otherwise remained with parents or other relatives rather than attending center-based care is now well-established for many outcomes, cognitive and otherwise. Yet, while specific interventions within some pre-k or HS settings have been evaluated for effects on participants' EF outcomes (e.g., Bierman, Nix, Greenberg, Blair, and Domitrovich, 2008), no prior studies have examined, more generally, the effects of child care or type of child care on EFs. This paper expands earlier exploration of whether Head Start boosts children's development by examining participants' EF skills at kindergarten entrance, as compared to similar children who experienced alternative types of child care. Since it is understood that EFs predict academic growth in early grade school, it is surely important to know whether and to what extent EF development is supported by HS participation. In particular, children without access to center-based care other than HS can be thought to be among the most disadvantaged children in the U.S., and so the effectiveness of any intervention on any important outcome merits close examination.

I expect to find a similar pattern of significant positive effects of Head Start on working memory and cognitive flexibility for those children (similarly matched on critical characteristics predictive of cognitive function) who attended HS in place of parent or relative care in their prekindergarten year. However, researchers continue to build an understanding of the codevelopment of children's cognitive abilities, social skills, and motor skills across time. If I do not find consistent effects on EF skills for any children at kindergarten entrance, a positive HS effect may emerge a year or two later in their school careers, particularly for those children who attend schools where their opportunities are rich enough to magnify some early advantages, however difficult to detect early on, initiated through the program's resources.

To provide full context and because the effects of HS have been shown to vary by comparison group, I shall also provide analysis of HS effects on EFs for children who would otherwise have attended public pre-kindergarten, other center-based care, or care provided informally by non-relatives.

Data and Methods

Analytic sample:

For the cohort of the ECLS-K:2011 study, the National Center for Educational Statistics (NCES) conducted a nationally representative longitudinal survey of approximately 18,150

American children who entered kindergarten in the fall of 2010, drawn from 950 schools to ensure appropriate sampling by race, ethnicity, and socioeconomic background. The Study then followed these children through the spring of fifth grade. Information collected over that time included interviews conducted with parents, teacher and school administrator surveys, teacher assessments of individual children, and direct assessments of the children's cognitive and motor abilities, enabling a comprehensive data source of children's early learning and school progress through their middle childhood years.

My three-paper investigation will implement data from six waves, including survey data from interviews conducted with parents, teacher assessments, and direct assessments of the children's cognitive abilities in both fall and spring each year from kindergarten entry through the spring of second grade. This first paper will explore how children perform at the start of kindergarten, through cognitive scores and teacher assessments, with special reference to the type of care they received in the year before starting school. Preschool care types and other child and family characteristics are taken from parent survey data collected during the fall and spring kindergarten waves. I excluded children for whom the Study was missing EF assessment data in the fall of kindergarten (following Conway, Waldfogel, and Yang, 2018) as well as those who were not first-time kindergarteners, or were missing information on age, gender, race/ethnicity, or parent survey information on early care arrangements in the year before kindergarten. Approximately 12,900 children remained in the full analytic sample[3].

Early care arrangements

[3] In accordance with NCES reporting rules, all sample sizes were rounded to the nearest 50 children.

In order to estimate HS effects in comparison with those of alternative care arrangements, I created mutually exclusive variables for the primary type of care children experienced in the year before kindergarten, using information provided in parent surveys in the fall and spring kindergarten waves of the Study. First, I coded children who attended center-based HS in the year before kindergarten as HS participants, even if they also received another type of childcare during that year. Next, I designated children who attended state-sponsored center-based care that was not a HS program and was located in a school as school-based public pre-kindergarten participants. Children who attended any other type of center-based care I designated as "other-center based" participants. Next, I coded a group of children who did not attend center-based care and received care from relatives or non-relatives (i.e., informal care) for at least eight hours per week as another group (following guidelines set forth in Lee et al., 2014 and Zhai et al., 2011). Finally, I coded children who were not already in any of the early care groups as "parent-only" care recipients. To be clear, children were assigned to the parental care group if they received informal care from relatives or non-relatives for less than eight hours per week. Although some children experienced more than one type of care, the surveys provided sufficient detail that it was possible to establish which children attended primarily center-based Head Start (about 15%), a school-based pre-k program (over 11.5%), other center-based care (42%), or were cared for informally by either relatives or non-relatives (10.5%), or exclusively by parents (20%).

Outcome measures

Executive functions

Critically, ECLS-K data includes periodic measures of children's cognitive flexibility and working memory skills, beginning in the fall of kindergarten, even for those children who required that the test be administered in Spanish (Tourangeau, Nord, Le, Sorongon, Hagedorn, Daly, and Najarian, 2015)[4]. In kindergarten (and through first grade), children's cognitive flexibility was measured by a table-top version of the Dimensional Card Change Sort task, using 22 cards displaying either a blue boat or a red rabbit (Zelazo, 2006). After four practice items, children attempted to sort six cards by color and then to "switch rules" by sorting six cards by shape. (Younger children will perseverate by reverting to switching by color on the shape trials, but by age five most children can switch successfully.) If the children were correct on four of the six "post-switch" trials, they were given the task of sorting six more cards in a third "border" task, following a slightly more complex rule; if the card had no border, they were to sort it by shape, and it had a black border, they were to sort it by color. Children's working memory was measured by a backward digit span task, the Numbers Reversed task of the Woodcock-Johnson III Test of Cognitive Abilities (Woodcock, McGrew, and Mather, 2001). In this task, children were asked to repeat in correct reverse order a series of numbers read aloud to them, beginning with a five series of two-digit numbers, and increasing through progressively larger series of numbers, until they have either answered three consecutive series incorrectly or finished responding to the series of eight-digit numbers. Scores on this measure ranged from 0 to 30; notably, given the especially strong predictive link of WM with achievement, only 61.3% of the kindergarteners in the analytic sample were unable to answer any of the Numbers Reversed trials correctly, and among children who had attended HS, just 47.1% of them were unable to do so.

Following Carlson (2005) and Conway, Waldfogel, and Wang (2018), I analyze performance on the Standard DCCS (including Color and Shape tasks) separately from the Advanced DCCS (Border task only). The correct total number of cards each child correctly sorts in both the Color and Shape tasks (ranging from 0 to 12) is the Standard DCCS score, and the

[4] Fewer than 2% of the total analytic sample required assessment in Spanish in the first wave.

correct number of sorted cards in the Border task (ranging from 0 to 6) is the Advanced DCCS score; both of these scores were standardized (Mean=0, SD=1). The raw Numbers Reversed score for each child (ranging from 0 to 30) was also standardized (Mean=0, SD=1). Additionally, I calculate a composite EF score by averaging the raw Advanced DCCS, Standard DCCS, and Numbers Reversed scores and standardizing the resulting mean to provide a Composite EF score (M=0, SD=1). The full analytic sample's composite EF includes values ranging from -3.37 SD to +5.15 SD. For HS participants, the mean composite EF score falls -.32 SD below the mean of the full analytic sample, the HS participants' composite EF ranges from -3.37 SD to +2.31 SD.

Because HS participants typically grow up in particularly disadvantaged families and exhibit lower than average cognitive outcomes, I analyse an additional outcome to test a hypothesis that HS may provide advantages for children near the bottom of the distribution of EF capabilities. For cognitive flexibility, I analyze a separate continuous outcome reflecting ability in one of earliest preschool competencies, color identification, by creating a separate continuous outcome for the "Color" task; this outcome, ranging from 0-6, is the actual number of correct answers children were able to provide on that first portion of the DCCS, and I standardize it (M=0, SD=1). In order to investigate competency exceeding average levels for disadvantaged children, since it is possible that HS might enable achievement for some children with relatively stronger abilities, I provide estimation of a continuous measure of Numbers Reversed for only those children who obtained a positive score on the task.

In addition, teachers provided assessments of each child's Inhibitory Control (IC) and Attentional Focus (AF) by filling out a short, modified form of the Child's Behavior Questionnaire, with six questions to assess each construct (CBQ) (Putnam and Rothbart, 2006). For this form, the teachers had to evaluate statements about how children were likely to have responded to certain situations in the previous six months with measures ranging from "extremely untrue" to "extremely true." Their answers were averaged to provide the assessment scores included on the ECLS-K file, which range from 1 to 7. Both measures have an internal consistency reliability of .87 (Tourangeau, et al., 2015). I include both of them in this analysis since attentional focus and IC are both components of the EFs more formally measured by the Study, and teacher perceptions of behaviors in classroom contexts are especially relevant. I standardize the measures (M=0, SD = 1), and average scores for children who attended HS before kindergarten are -.21 SD for inhibitory control and -.22 for attentional focus (slightly higher than their average composite EF score).

Reading and math skills

ECLS-K staff administered IRT assessments in both reading and math during the fall of kindergarten. I standardized these scores (M=0, SD=1). For HS participants, the mean reading score is -.29 SD below the mean of the full analytic sample, and their mean math score falls -.35 below the full group mean; both scores are close to the mean composite EF score for this group (-.32 SD). Interestingly, similar levels of EF skills appear to support children in their academics differentially; the especially disadvantaged children who attended HS with composite EF scores near -1.0 SD ($n \approx 200$) attained an average reading score of -.58 SD and an average math score of -.73 SD, while non-HS children scoring similarly on composite EF ($n \approx 950$), attained an average -.38 SD in reading and -.41 SD in math. Along the distribution of EF skills for the ECLS-K:2011 cohort, this disparity appears somewhat consistent for both reading and math, so that HS participants appear to "get less" out of their EF skills in terms of academic achievement than do many other children, at least for this sample at the start of kindergarten. Further exploration of these disparities, presented in Supplementary Figures, suggests that the difference is related less to the type of care children receive than to differences in income-to-needs and parental education, which presumably helped to determine childcare selection. (Additionally, these views demonstrate that the relationship between measures of parental education and working memory is more clearly linear than that between parental education and cognitive flexibility.)

Behavioral assessments by teachers:

In addition to teacher's ratings of executive skills (IC and AF), I also analyze teacher assessments of students' internalizing and externalizing behaviors derived from answers to a short form of the Social Skills Rating System (NCS Pearson 1990), with four responses for the internalizing assessment and six for the externalizing assessment. Higher scores on these measures indicate more problematic behaviors. Research has traced increases in externalizing conduct for participants of HS as well as other nonparental care, increases that do not persist, on average, as children transition into the first few years of school (Pingault, Tremblay, Vitaro, Japel, Boivin, Cote, 2015). These measures I also standardize (M=0, SD = 1), and average scores for children who attended HS before kindergarten are .01 SD for internalizing behaviors and .19 SD for externalizing behaviors.

Approaches to Learning (ATL), a teacher rating of children's readiness for learning and appropriate classroom behaviors, has been investigated in other cohort data as a potential stand-in for EF measures (Duncan, et al., 2007) and for its relative effects on children's academic and social competencies (Razza, Martin, and Brooks-Gunn, 2015). The ECLS-K:2011 also culled from the Social Skills Rating System a selection of seven questions for teachers about how well children organized their belongings, demonstrated eagerness to learn, worked independently, persisted in completed tasks, adapted to shifts in routine, paid attention, and followed rules when in school (Tourangeau et al, 2015). Answers to these questions were averaged to provide the assessment score, which I then standardized (M=0, SD = 1). The average score for children who attended HS on ATL is -.186 SD, significantly lower than the mean for the full analytic sample but not as far below the mean for the full group as their cognitive scores, and slightly higher than the teacher assessments of this group's Inhibitory Control (-.208 SD) and Attentional Focus (-.223).

Predictors:

The ECLS-K provides rich predictors of both Head Start participation by children and their families and measures of disadvantage which affect children's early cognitive abilities. I controlled for individual, maternal, and family characteristics, including the child's gender, race/ethnicity, and age at the time of assessment as well as low birthweight, since children born with lower than average birthweight are at risk for lower levels of executive functioning at kindergarten entrance, in both cognitive flexibility and working memory (Miller, DeBoer, and Scharf, 2017). Following Conway et al. (2018), I coded maternal education level as a categorical variable (Less than high school, high school, some college or vocational degree, or Bachelor's degree and above). I included maternal employment (employed full-time, part-time, or not working) and a continuous variable for the mother's age at the first birth of her child, as well as an indicator variable for the self-reporting of poor maternal health (1= "yes", 0= "no"). Family demographics included whether the family was living either below the poverty threshold, near poverty (between 100% and 199% of the threshold), or above poverty (200% or above the threshold). Family structure (two parents, a single parent, or other guardian), parent immigration status (at least one parent an immigrant or both parents born in the US), as well as English or non-English home language were also included in my models. Finally, my analyses include three indicators for receipt of social aid programs, since these can be predictive of both Head Start participation and child cognitive outcomes: current participation in the WIC nutritional program, participation in the last twelve months in the SNAP (food stamp) program, and participation in the last twelve months in the TANF (cash transfer) program.

Rates of missing data on the predictors described in this sample ranged from .33% for maternal education to 33.8% on immigration status in the analytic sample. In order to retain the full analytic sample of 12,900, I estimated missing data with multiple imputation using chained equations and implementing predictive mean matching, as needed, to create five complete datasets with imputed values for the missing covariate predictors. (As part of the imputation modelling, variables were extensively tested using recommended diagnostics (Eddings and Marchenko, 2012)). In the analysis of outcomes, I estimated separate coefficients and standard errors through OLS and matching methods for each imputed dataset and combined these using standard procedures to adjust for uncertainty within and between imputations (Rubin, 1976; Rubin, 1987).

Methods:

Because children in the ECLS-K were not randomized for HS participation, I must employ nonexperimental methods to account for selection bias, beginning by providing OLS estimates with controls including the many predictor variables. These unmatched estimates appear in Tables 3, 4, and 5.

To address continuing concern that each of the comparison groups, as defined by alternative care type in the year preceding kindergarten, includes children from varied and often more advantaged backgrounds than HS participants, I employ a multi-step propensity score method separately for each alternative care group to provide “matched” estimated effects in subsequent “matching” analyses. By comparing the outcomes of HS participants only with those children who share highly similar characteristics (and thus, a highly similar probability of attending HS), and adjusting regression models for the comparison by weights generated through the propensity score model, I can assume “strong ignorability” and infer that the results are not affected by selection bias (Rosenbaum and Rubin, 1983; Rubin and Thomas, 2000; Hill, 2008).

In the first step of this method, a probit model generates propensity scores calculating the probability of HS enrollment in the “treatment” group (attending HS) for every child in the full analytic sample, whether actually an HS participant or not, based on child, parent, and family characteristics (as well as the appropriate ECLS-K survey sampling weights). In this way, each HS participant is matched, through their score, with only those non-HS children who have a sufficiently similar probability of HS enrollment. Based on examination of covariate balance across the HS and non-HS groups (adjusted by the probability weights) resulting from these estimation models, I selected as a matching method a kernel caliper of .01, so that each HS child was optimally “matched” to all children with a propensity score within .01 of their own, and comparison children outside of that distance were discarded from estimation[5]. Children within that distance, under the kernel caliper method, were assigned weights adjusted by the distance from the HS child to which they were matched in order to further reduce bias. In all final matching models, the final analytic subgroup excluded between one and twenty Head Start participants, for whom sufficiently close matches were not found. (This requires the use of the “common support” option in STATA. Discussion of what types of children were excluded in each subanalysis follows in Appendix A.) Covariate balance for each matching estimation is provided in Table 2 (with means adjusted by propensity scores for each subgroup as compared to

[5] Caliper sizes investigated for optimal matches following Austin, 2011.

the HS group after matching). Finally, I estimated effects using regression adjusted by propensity score weights, resulting in the "PSM" estimated effects of HS with other care types presented in Tables 3, 4, and 5, which are presented alongside the OLS estimates for comparison.

Findings

Descriptives

Table 1 presents descriptive statistics of child, maternal, and family predictors, as collected in study data and parent surveys in the spring of kindergarten (2011), as well as the group means for outcomes measured in the fall of kindergarten and teacher assessments. These statistics are presented by types of childcare arrangements in the year preceding kindergarten (adjusted by sampling weights and jackknife replicate weights).

Predictor means in the first column make clear the disadvantages that HS children experience. Child demographics for the group of HS participants group indicate that it includes the highest percentages of black (25.%) and Hispanic (32.4%) in the sample and the highest proportion of children born with low birthweight (10.9%). The mothers of these children have the lowest mean age at the birth of their first child (21.2 years), and the highest proportion of mothers with a high school level of education (31.5%) and the lowest proportion of college-educated mothers (11.3%). Interestingly, most HS mothers have either some college or a technical degree (37.3%), but most report themselves as either not working (40.5%) or working full-time (40%); these mothers are more likely than those in other care groups to self-report their health as poor (16%). Of all groups defined by early care type, the HS families are most likely to have a single parent (34.9%) as well as the highest likelihood of living below the poverty threshold (48%), with the highest levels of program receipt for WIC (81.7%), TANF (14.6%), and food stamps (56%). Over 40% of the HS families have at least one immigrant parent, with a non-English language the primary household language in 21.6%, second only to those families selecting parent-only care (24.7%).

In contrast, the group of children who attended school-based prekindergarten is relatively advantaged, with almost half living over the poverty level, with 78.8% living in two-parent families, and just 21.9% below the poverty level. Most mothers in this group have either some college or a vocational degree (36.9%) or a college degree (or more) (27.9%). Only about ¼ of these children have at least one immigrant parent (26.8%). Although pre-kindergarten programs are often framed as government-provided services with the goal of equalizing young children's chance of academic success, they serve families with far more resources, on average, than HS families, making it important to counter selection bias.

Similarly, center-based care is a highly heterogeneous group. Parents with restricted means can obtain subsidized center care, while affluent parents choosing high-quality private care also belong in this group. On average, they are the most advantaged group: 67.3% of the children are white, and most (83.7%) live in two-parent families. Three-fourths live above the poverty level, with only 10.6% living below the poverty level. This group has by far the highest proportion of college-educated mothers (51.3%), with almost another third having attended some college or attained a vocational training certification (31.6%). Unmatched estimates of HS effects with this group will almost certainly be highly biased.

The two groups of children who received no center-based care before kindergarten are far less advantaged. In both the relative and non-relative informal care group and the parental care group, most children live either near or below the poverty level; 36.7% of the parental group and 30.1% of the relative and non-relative group live under poverty, with 27.4% of the parental group and 36.7% of the relative and non-relative group living near poverty. A higher proportion (22.8%) of mothers in the parental group have less than a high school education, compared to

15.5% of those in the relative and non-relative group. Relative and non-relative care group children have a much higher proportion of single-parent families (34.2%), with the parental care group having just 17.3%. Parental care group children have a higher proportion of two-parent families (80.6%); just 63.5% of relative and non-relative care group children live with two parents. Interestingly, both groups appear to somewhat less likely than the HS group to receive benefits, which may account for their non-receipt of HS services since sometimes administrative benefits offices make parents aware of options for their childcare. The parent-only group has the second-highest proportion of families with at least one immigrant parent (37.5%), second only to HS. This group features the highest proportion of households in which English is not the primary language (24.7%), followed by HS (21.6%). In general, these two groups exhibit levels of disadvantage more similar to the HS group, although not as severe on some measures. Careful matching and separate analysis are warranted for these groups as well.

On almost all outcome measures, including EF measures, HS participants in the sample exhibit significantly lower average levels of performance than children in most of the alternative care groups. Notably, on the continuous Numbers Reversed outcomes HS participants score on average -.327 SD below the full sample mean, with all other groups scoring significantly higher; when restricting analysis to those children who were able to score above zero on this assessment, the average score of HS children was over 1/5 SD below the mean for the full sample and still well below the averages for other care groups. On composite EF measures, HS children scored on average -.32 SD below the sample mean. Exceptional measures on which the HS sub-sample scored higher than other groups include the Color sub-task on the DCCS; on this measure it appears that HS participants attained a slightly higher average score (-.029 SD) than the group of children who experienced only parental care (-.042 SD), though this difference is not statistically significant. This summary view also suggests that children who experienced either informal care by relatives or non-relatives and children cared for by their parents had slightly higher rates of internalizing behaviors than HS participants.

The group of children in comparison with whom HS has demonstrated to have positive effects on outcomes in previous research, those cared for only by their parents in the year preceding kindergarten, demonstrates similarly low average outcomes on most EF measures, IRT tests, and teacher assessments in the analytic sample. That outcomes are not as low as those for the HS participants may stem from heterogeneity in this group; some more advantaged parents simply prefer to allocate the resources of one parent to early childcare, and since parental education drives early EF development to a great degree (Conway, Waldfogel, and Wang, 2018), the outcomes are likely mixed as a result of relatively rich home environments for some children in the parent-only group. Such within-group mixtures of important characteristics underscore the importance of employing matching methods to reduce selection bias.

In comparison, children attending center-based care have the highest average outcomes on all cognitive assessments and every teacher assessment but one (externalizing behaviors, in which children cared for by parents have a slightly better average score). Since families who send their children to center-based care (other than HS or pre-k) include highly advantaged families able to provide optimal home environments and to afford high-quality early care, many of the children in this subgroup have experienced about five years of enriching early cognitive development by the time they reach kindergarten entrance. Other forms of center-based care can feature less enriching settings, such as subsidized center care selected by less advantaged families, so that this is a heterogeneous group; however, the efforts of the most educated, high-income parents have sufficiently strong effects on their children that the average composite EF score for this group is almost 1/4 of a standard deviation above the full sample mean.

Analysis

The results of OLS and matching estimation are presented in Tables 3 and 4 for all analyses of EF skills, and in Table 5 for reading and math scores as well as the three teacher assessments of internalizing and externalizing problems and ATL behaviors. Fully controlled OLS estimates of unmatched children compared across groups defined by alternative care show no positive or negative effects on the working memory of HS participants who, in the absence of the program, would have been cared for exclusively by parents; similarly, no effects for HS on working memory in these children result from closely matched comparisons. However, both OLS and matching methods demonstrate slightly higher scores among HS participants on cognitive flexibility measures in comparison with children who received only parental care; HS participants achieved higher average scores than closely matched children on the Standard DCCS tasks (ES=.100, $p<.05$) and on the Advanced DCCS (ES=.074, $p<.05$). Teacher ratings of executive abilities in inhibitory control and attentional focus exhibit no significant differences for HS participants in comparison with the parent-only care group, but their average composite EF measure is slightly higher (ES=.068, $p<.05$), reflecting the positive effects on the Standard and Advanced DCCS tasks.

On behavioural teacher assessments, both OLS and matching methods exhibit mixed results on internalizing and externalizing problems in HS children in comparison with children of the parent-only care group. The children who participated in HS exhibit somewhat fewer internalizing problems than closely-matched children (ES=-.094, $p<.05$), but more externalizing problems (ES=.123, $p<.001$). There is no HS effect on the Approach to Learning assessments in the parent-only comparison. However, consistent with other studies, HS appears to benefit participants' academic scores when compared to those of children who received only parental care; matching estimation here yields small advantages in both reading (ES=.111, p<.01) and math (ES=.104, p<.01).

Close comparison of HS participants to closely matched children who received care from relatives in informal settings demonstrates no effects on working memory, with very slight evidence for a positive effect on the Standard DCCS (ES=.068, p<.10). No effect on composite EF was demonstrated by these comparisons. Further, teachers gave the HS children significantly lower average assessments on inhibitory control skills when compared with the relative-only group (ES=-.085, p<.05), and higher measures of externalizing problems at school (ES=.123, p<.001). The HS children achieved slightly higher scores in reading (ES=.101, p<.01) and math (ES=.072, p<.05) in comparison with the relative-only group.

OLS estimation comparing HS children to those children who attended school-based pre-k suggests small negative HS effects on most of the working memory measures, and a smaller negative effect on the Color Score portion of the DCCS task, with no overall differences on most cognitive flexibility measures. After matching estimation accounts for selection bias, the negative HS effects on Numbers Reversed remains small and significant (ES = -.092, p<.01 for full range of scores). HS participants exhibit a small average deficit on the Color Score of the DCCS as closely-matched children who attended school-based public pre-k programs (ES=-.078, p<.05), although overall there appears to be no significant difference between the two groups' cognitive flexibility. The HS effect on composite EF scores is -.062, p<.10). Small but significant negative effects estimated from comparison of closely matched children who attended pre-K were also found on teacher assessments related to EFs and school behaviors: inhibitory control, ES= -.071 SD, p<.10; attentional focus -.110, p<.01); and approaches to learning, ES= -.093 SD, p<.001. Negative HS effects emerged for reading (ES=-.090 SD, p<.001) and math

(ES=-.092 SD, p<.001) IRT scores, as well as on several teacher assessments. These findings support other research suggesting that, for children from lower-income families, many pre-k programs provide richly supportive learning environments that are preferable in comparison to HS for children's cognitive outcomes, including their EF skills.

Since children in the center-based care group lived in more advantaged families, on average, than those attending HS, matching estimation in order to account for selection bias is particularly important in this set of analyses. Estimation for closely matched children suggests small, significant negative HS effects on all working memory outcomes, continuous or dichotomous. In particular, HS participants have lower average scores on the Numbers Reversed task than closely-matched children in this group (ES=-.122, p<.001) as well as on the advanced DCCS (ES=-.061, p<.05). They attain lower average composite EF scores (ES=-.108, p<.01). They receive lower average teacher assessments on attentional focus as well (ES= -.110, p<.01). The greatest negative HS effects in comparison to any group are found on reading (ES=-.132, p<.01) and math (ES=-.170, p<.001).

Discussion

The findings here support the idea that ECE programs prepare disadvantaged children to begin formal schooling to varying degrees. That HS participants achieve slightly higher reading and math scores at kindergarten entrance, on average, in comparison with closely matched children who did not attend center-based care is unsurprising in view of prior research. It is also fairly clear that HS participants did not score as well on either reading or math when compared to closely matched children who attended either school-based pre-k or other center-based programs, even accounting for selection bias. This too is generally consistent with other studies.

The differential findings regarding EFs are somewhat more complex. Children who attended center-based care that was either public pre-k or other center-based care did, on average, attain significantly higher working memory scores than HS participants, roughly corresponding with their relatively higher scores (also in comparison to the HS group) in reading and writing. Somewhat surprisingly, the HS participants seemed to achieve higher average reading and math scores than the parental and relative care groups *without benefit* of a corresponding boost in their working memory abilities in comparison to those groups. Schager et al. (2013) suggest that HS analyses involving outcomes that are not closely tied to HS curriculum (they cite vocabulary and IQ as examples) typically do not demonstrate positive effects, even in comparisons restricted to parental care, so perhaps this non-finding on working memory is not surprising.

When tasked with the shapes, colors, and rules changes of the DCCS, however, the HS group attained slightly better scores than the parental care and relative/non-relative groups, suggesting that these elements form a standard part of the average HS curriculum. We also know that up until age six, cognitive flexibility often grows in inverse relationship with other EFs (Jones, Rothbart and Posner, 2003), until development brings about integration of these distinct abilities; it could be that the HS participants remain in a stage of development in which this integration is less available to them than to students who have experienced less disadvantage. Whether the HS participants' slight but significant advantage in reading and math actually stems from improvements in their cognitive flexibility is unknown. Recent study of kindergarten classroom practices suggests that certain instructional settings seem to support growth in cognitive flexibility, but *not* in working memory, at least for some children (Ansari and Purtell, 2017). However, we cannot specifically trace effects here to an analysis of HS or other ECE characteristics; the ECLS-K does not provide measures of expenditures, quality, curriculum, teachers, or format for any programs that children attended before kindergarten entrance. It does seem that the type of cognitive priming offered in the average HS program fostered sufficient foundational skills, in contrast to those acquired by children lacking center-based experiences, to achieve the small academic and EF gains detected here.

A related issue is how well, on average, HS supports non-cognitive skills, including as the teacher assessments of classroom behaviors examined here. At least one study with focus on alternative care types has found that HS participants enter school prepared with greater social competence and fewer externalizing behaviors than children who attended other center-based care (Zhai et al., 2014). Findings here suggest a contrasting pattern, in which students' social behaviors after HS are indistinguishable from those of children in other center-based care. While externalizing behaviors frequently seem to fade as children progress into middle school, they should be considered alongside findings here of negative HS effects on teacher assessments of attentional focus arising from analysis against both the school-based pre-k and center-based comparison groups, and, from analysis against the pre-k group, the negative effect on Approaches to Learning: ES=-.093, p<.01). That the ATL outcomes of HS participants do not demonstrate improvement over children lacking center-based care while exhibiting negative effects in comparison with closely matched prekindergarten children is especially concerning, since exploration of this measure has found its positive development to augur academic benefits in particular for disadvantaged children with lower early social-emotional skills (Razza, Martin, Brooks-Gunn, 2015).

That HS children on average have more difficulty managing their classroom behaviors in kindergarten may actually suggest something important about their low EF skills *and* the relatively small effects on reading and math (when compared to abilities of children who attended other forms of center-based care). Monette, Bigras, and Guay (2011) highlight the indirect effect of working memory and inhibitory control on both reading and writing scores by the end of first grade via anger-aggression. They posit that EFs (and related self-regulatory competence) may matter even more to children's reading skills as they get older. Seen in this light, the pattern of all HS effects in this study suggests reasons for taking both EFs and related social-emotional skills seriously in the year(s) preceding kindergarten. Other work suggests that, even after controlling for maternal education and children's verbal skills, social-behavioral adjustment mediates the relation between EFs and children's academic readiness (Baptista et al., 2016).

It may be that many of the children who enter HS require more from the program in this area than even many disadvantaged children who attend pre-k programs. Chaudry et al. (2017) note the strong quality of emotional support in U.S. preschool programs, including HS, but the rates of externalizing seen in the ECLS-K data, together with other less than optimal results, suggest that additional work in HS could result in improvements across multiple outcomes. In fact, experimental use of special curricular programs in HS centers supports this. An evaluation of the HS REDI program targeting especially challenged children across 44 classrooms in 25 HS centers with an intervention specifically promoting social competencies, emotion regulation, and control of aggressive impulses, has found positive EFs and academic outcomes in third grade, with particularly large benefits for the group of children initially scoring lowest in EFs (Sasser, Bierman, Heinrichs, and Nix, 2017).

Limitations

Because the ECLS-K provides no assessments earlier than kindergarten, this study cannot include any baseline measurement of children's EFs from before their experiences in HS. However, we do know that by the age of two, cognitive ability is strongly predicted by families' income and level of parental education; not only do I control for these characteristics using numerous variables providing information about families' level of disadvantage (and strategies for countering them, such as employment and benefit receipt) for each child, I've also compared each HS participant to closely-matched children within each alternative care group, discarding control children who are very different from the HS participants and therefore unlikely to have developed stronger EF skills before preschool. Nonetheless, having a "pre-score" of children's earlier EF skills at age three would sharpen the estimates presented here.

It is also important to remember that increasingly, children begin HS at age three, and we have no indication of whether ECLS-K students have had the benefit of two years of the program or just one. Some, in fact, may have attended HS at age three and moved to another program, such as school-based pre-k, at age four. Having this information would doubtless shed even more light on the role of ECE programs in the early development of EF abilities and related outcomes.

Robustness check

Analyses after removing all children from the analytic sample who had received a diagnosis of disability by the start of kindergarten yielded results that were essentially unchanged. Such children are important to consider because, while they attend HS in higher numbers because of the program's mandate to serve them, the inclusion of their outcomes could bias analyses; on average, their EF skills can be lower than those of other children.

Supplementary analyses

In order to investigate variation in HS effects by children's gender, I re-ran analyses for HS and parent-only comparisons separately for boys and girls. Results suggest significant variation in effect sizes by gender; one example is that in comparison to the parent-only group, HS participation appears to boost boys' average math and reading scores an additional .5 SD, on average, more than it does for girls. Variation by gender on the EF outcomes was less evident. Overall, results suggest a need for further exploration of gender-based differences in the effects of early care interventions. See tables in Appendix B.

In order to test the hypothesis that HS may provide advantages for children at the very bottom of the distribution of EF capabilities, I estimated effects on a binary outcome indicating whether the child did (“1”) or did not (“0”) achieve a positive score on the Numbers Reversed task at the outset of kindergarten. This outcome enables evaluation of the likelihood that a particular type of ECE enabled certain children to cross that early threshold of WM competency. In order to measure the likelihood of children exhibiting competency at particular “threshold” dichotomous measures of the DCCS, I then analyse binary outcomes indicating whether (“1”) or not (“0”) children were able to score any positive responses on the Shape task (another low-level threshold, indicating whether children are able to resist perseveration). In order to examine EF outcomes that would demonstrate competency exceeding average levels for disadvantaged children, I provided estimation for two additional binary outcomes measuring working memory: whether (“1”) or not (“0”) a child who obtains a score above zero manages to proceed to three-digit series of numbers on the Numbers Reversed task, whether (“1”) or not (“0”) they proceed to four-digit series. To investigate effects on children with stronger competence in cognitive flexibility, I provide analysis of a binary measure of whether (“1”) or not (“0”) children proceed to the Border section of the DCCS task and another such measure of whether (“1”) or not (“0”) children score above 1 standard deviation above the mean on the Border task. Results, which fall in line with the estimation of effects on continuous outcomes, are provided in Appendix C.

Next Steps

Much of the literature on persistence of ECE program effects in the early school years focuses on the experiences of a somewhat more middle-class subgroup than HS children, targeting pre-k children in particular (Ansari, 2018); it is therefore even more important to look at how interventions in these years specifically affect HS participants. Therefore, in two subsequent papers I plan to examine development of HS participants' EF skills and related outcomes through second grade and compare them with children who experienced other care arrangements before beginning kindergarten.

Engel, Claessens, and Finch (2013) find that most kindergarten math instruction is "mis-aligned" with students' average existing capabilities (in the effort to help some students catch up); they demonstrate as well that while more advanced curriculum fosters math achievement in most students, some remedial students do benefit from time spent on basic instruction. In paper #2, I plan to investigate whether time with more advanced math topics is effective in supporting HS participants' achievements and EF development, in comparison with children from other groups, both during kindergarten and during the subsequent two years.

Interestingly, Bitler, Hoynes and Domina (2014) find persistent HS effects for Spanish-speaking students through first grade. In a third paper, I shall use elements from the previous two papers to examine closely the EF development of the children of immigrants; some of these children struggle in early school with issues relating to language learning, but often perform extremely well on math in the early years of school. Children of immigrants make up a high proportion of my full analytic sample (30.1%), and about 1/3 of these live below the U.S. poverty level. HS participation among immigrants can be low in some areas, and yet in other areas it may be parents' best or only ECE option. It is important to look more closely at what gains children of immigrants make *after* HS participation and, in particular, what happens to their EF skills and related outcomes once they are in school, in the context of home language, parent education, and math instruction.

Tables

Table 1. 1: Descriptive Statistics by Head Start and Other Care Arrangements, Unmatched Samples

Variable	Head Start (n≈1,950)	Pre-K (n≈1,500)	Center-Based Care (n≈ 5,550)	Relative/ Non-Rel. Care (n≈1,350)	Parental Care (n≈ 2,600)
Child characteristics					
Gender					
Female	.467	.470	.492*	.521**	.487
Male	.533	.530	.508+	.479**	.513
Age at assessment (in months)	66.9	67.5***	67.3**	67.1	67.2*
Race/ethnicity					
White (non-Hispanic)	.321	.530***	.674***	.451***	.464***
Black (non-Hispanic)	.255	.109***	.087***	.163***	.125***
Hispanic	.324	.267**	.133***	.300	.318
Asian (non-Hispanic)	.032	.023+	.053***	.031	.037
Other (non-Hispanic)	.068	.071	.054+	.055	.055
Birthweight					
Normal birthweight	.891	.913+	.930***	.916*	.899
Low birthweight (< 2500 g)	.109	.087+	.070***	.084*	.102
Child has diagnosed disability (parent report)	.216	.294***	.186*	.185+	.177*
Maternal characteristics					
Age at child's birth (years)	21.2	23.7***	26.5***	22.1***	22.7***
Education					
Less than high school	.199	.122***	.035***	.155**	.228*
High school graduate	.315	.230***	.136***	.293	.277*
Some college or technical	.373	.369	.316***	.392	.299***
College graduate	.113	.279***	.513***	.160***	.196***
Employment status					
Full-time	.400	.425	.486***	.618***	.207***
Part-time	.195	.195	.233**	.203	.180
Not working	.405	.380	.281***	.179***	.614***
Mother's health = poor (self-rated)	.160	.089***	.055***	.118*	.124*
Family characteristics					
Family structure					
Single parent household	.349	.193***	.150***	.342	.173***
Two-parent household	.619	.788***	.837***	.635	.806***
Other guardians	.031	.019*	.012***	.023	.021*
Number of siblings					
No siblings	.160	.133+	.170	.170	.116***
One sibling	.368	.413*	.482***	.395	.334*
Two or more siblings	.472	.454	.348***	.435+	.550***
Poverty status					
Above 200% of poverty level	.254	.498***	.740***	.417***	.359***
Near poverty level	.266	.283	.154***	.282	.274
Below poverty level	.480	.219***	.106***	.301***	.367***
Benefit receipt					
WIC receipt (current)	.817	.555***	.286***	.644***	.606***

Table 1. 1: Descriptive Statistics by Head Start and Other Care Arrangements, Unmatched Samples

Variable	Head Start (n≈1,950)	Pre-K (n≈1,500)	Center-Based Care (n≈ 5,550)	Relative/ Non-Rel. Care (n≈1,350)	Parental Care (n≈ 2,600)
Welfare receipt (# months in past year)	.146	.063***	.038***	.102**	.114**
Food stamps receipt (# months in past year)	.560	.319***	.150***	.369***	.437***
Parent immigration status					
Only U.S. born parents	.592	.731***	.810***	.715***	.625
At least one born outside U.S.	.408	.268***	.190***	.285***	.375
Primary language in household					
English	.767	.844***	.925***	.829***	.741+
Non-English	.216	.141***	.068***	.157***	.247***
Child assessed in Spanish in Wave 1	.018	.024	.002***	.025	.051***
Family lives in urban area	.801	.678***	.811	.755**	.770*
Region of residence					
Northeast	.151	.126**	.184**	.114**	.133
Midwest	.220	.246	.259**	.244	.154***
South	.375	.456***	.335**	.373	.416*
West	.254	.172***	.222**	.268	.297**
Outcomes					
Continuous EF Measures					
Numbers Reversed	-.327	-.023***	.241***	-.216**	-.204***
Numbers Reversed (above zero)	-.218	-.025***	.103***	-.152	-.096**
Standard DCCS (Color and Shape)	-.145	.032***	.116***	-.071+	-.129
DCCS sub-task (Color only)	-.029	.076**	.003	.033	-.042
Advanced DCCS (Border only)	-.197	.001***	.155***	-.078**	-.151
Composite EF	-.320	-.004***	.240***	-.187**	-.218**
Cognitive IRT Scores					
Reading	-.290	.021***	.301***	-.286	-.235+
Math	-.349	.002***	.343***	-.271*	-.272*
Teacher Assessments					
Inhibitory Control	-.208	.024***	.102***	-.028***	-.052***
Attentional Focus	-.223	.029***	.150***	-.121*	-.091***
Internalizing Behaviors	.001	.004	-.054+	.050	.081*
Externalizing Behaviors	.185	-.017***	-.032***	-.028***	-.050***
Approaches to Learning	-.186	.053***	.122***	-.106*	-.085**
	*** p<.001 ** p<.01 * p<.05 + p<.10				

Group means weighted by survey sample and jackknife weights. All sample sizes are rounded, in accordance with NCES guidelines, to the nearest 50 students.
All outcome measures are standardized (m=0, SD=1), excepting threshold measures, which are binary and therefore represent proportions of children in each group who accomplished each subtask or threshold.

Table 1. 2: Subgroup Means for Matching Estimation, By Care Type Subgroups (Predictors only)

Variable	Head Start (n≈1,950)	Pre-K (n≈1,050)	Head Start (n≈1,950)	Center-Based Care (n≈ 4,000)	Head Start (n≈1,950)	Relative/ Non-Rel. Care (n≈800)	Head Start (n≈1,950)	Parental Care (n≈ 1,700)
Child characteristics								
Gender								
Female	.461	.480	.462	.470	.462	.455	.464	.468
Male	.539	.520	.537	.530	.538	.545	.536	.532
Age at assessment (in months)	67.0	66.8	66.9	66.9	66.9	67.0	66.9	66.9
Race/ethnicity								
White (non-Hispanic)	.354	.353	.352	.353	.353	.352	.355	.347
Black (non-Hispanic)	.234	.222	.238	.249	.237	.245	.235	.220
Hispanic	.306	.332	.314	.298	.315	.315	.314	.329
Asian (non-Hispanic)	.039	.029	.039	.035	.039	.037	.039	.034
Other (non-Hispanic)	.057	.064	.057	.064	.057	.052	.057	.071
Birthweight								
Normal birthweight	.898	.900	.897	.894	.897	.897	.896	.897
Low birthweight (< 2500 g)	.102	.100	.103	.106	.103	.103	.104	.103
Child has diagnosed disability (parent report)	.212	.203	.209	.200	.211	.209	.206	.202
Maternal characteristics								
Age at child's birth (years)	21.7	21.6	21.7	21.8	21.7	21.7	21.7	21.7
Education								
Less than high school	.159	.157	.153	.148	.159	.159	.168	.175
High school graduate	.304	.304	.310	.318	.308	.312	.312	.316
Some college or technical	.399	.404	.309	.316	.401	.404	.391	.382
College graduate	.397	.419	.396	.391	.132	.125	.129	.127
Employment status								
Full-time	.397	.419	.396	.446	.396	.399	.389	.391
Part-time	.203	.188	.206	.192	.206	.212	.307	.195
Not working	.400	.393	.399	.362	.397	.389	.403	.413
Mother's health = poor (self-rated)	.146	.149	.156	.136	.156	.146	.155	.155
Family characteristics								
Family structure								
Single parent household	.319	.319	.323	.339	.323	.345	.316	.304

Table 1. 2: Subgroup Means for Matching Estimation, By Care Type Subgroups (Predictors only)

Variable	Head Start (n≈1,950)	Pre-K (n≈1,050)	Head Start (n≈1,950)	Center-Based Care (n≈ 4,000)	Head Start (n≈1,950)	Relative/ Non-Rel. Care (n≈800)	Head Start (n≈1,950)	Parental Care (n≈ 1,700)
Two-parent household	.660	.667	.656	.643	.656	.634	.663	.674
Other guardians	.021	.015	.021	.018	.020	.021	.022	.021
Number of siblings								
No siblings	.162	.155	.167	.176	.165	.166	.165	.171
One sibling	.390	.390	.389	.409	.389	.413	.388	.381
Two or more siblings	.447	.455	.444	.416	.446	.421	.447	.449
Poverty status								
Above 200% of poverty level	.260	.259	.259	.255	.259	.255	.251	.246
Near poverty level	.274	.271	.281	.287	.279	.288	.275	.274
Below poverty level	.466	.470	.460	.457	.462	.457	.458	.480
Benefit receipt								
WIC receipt (current)	.790	.799	.791	.798	.791	.800	.790	.807
Welfare receipt (# months in past year)	.552	.550	.149	.151	.149	.153	.151	.145
Food stamps receipt (# months in past year)	.552	.550	.554	.556	.553	.553	.551	.553
Parent immigration status								
Only U.S. born parents	.619	.636	.619	.659	.619	.618	.620	.634
At least one born outside U.S.	.381	.364	.381	.341	.382	.382	.380	.366
Primary language in household								
English	.696	.799	.797	.756	.796	.796	.797	.778
Non-English	.192	.184	.191	.163	.191	.192	.192	.212
Child assessed in Spanish in Wave 1	.019	.026	.019	.017	.019	.027	.018	.045
Family lives in urban area	.763	.771	.747	781	.764	.758	.763	.765
Region of residence								
Northeast	.135	.126	.135	.137	.134	.125	.133	.127
Midwest	.217	.206	.219	.212	.219	.209	.215	.199
South	.400	.438	.398	.431	.398	.411	.402	.413

Table 1. 2: Subgroup Means for Matching Estimation, By Care Type Subgroups (Predictors only)

Variable	Head Start (n≈1,950)	Pre-K (n≈1,050)	Head Start (n≈1,950)	Center-Based Care (n≈ 4,000)	Head Start (n≈1,950)	Relative/ Non-Rel. Care (n≈800)	Head Start (n≈1,950)	Parental Care (n≈ 1,700)
West	.248	.230	.248	.221	.249	.255	.251	.261

Means provided with post-estimation command “pstest” in STATA, using the “rubin” option: Rubin’s (2001) ratio of the variance of the covariates orthogonal to the linear index of the propensity score in the treated group over the non-treated group; these “Rubin statistics” indicated acceptable covariate balance for each model implemented. Also included in the model (not shown here) were survey weights.

Table 1. 3: Effects of Head Start on Continuous Executive Function Outcomes

	Working Memory Outcomes				Cognitive Flexibility Outcomes					
Task Measure	Numbers Reversed		"Non-Zero" Num Reversed		Standard DCCS		Color Score Only		Advanced DCCS	
	OLS	PSM	OLS	PSM	OLS	PSM	OLS	PSM	OLS	PSM
Reference care										
HS vs. Parental care (n ≈ 3,000)	.009	.013	-.033	-.036	.087*	.100*	.019	.025	.052+	.074*
HS vs. Relative/Non-relative care	.012	.007	-.033	-.017	.083*	.068+	-.016	-.027	.029	.043
HS vs. Prekindergarten	-.094**	-.092**	-.072	-.061	-.003	-.001	-.060+	-.078*	-.033	-.012
HS vs. Center-based care	-.122***	-.116**	-.142**	-.145**	-.036	-.044	.016	.032	-.070*	-.061*
	*** p<.001 ** p<.01 * p<.05 + p<.10									

All models include: child's gender. race and ethnicity, low birthweight, age in months at assessment time, indicator disability diagnosis; maternal age at birth of first child, educational level, maternal employment status, indicator of mother's health if poor, family structure, number of siblings in family, poverty status, current WIC receipt, TANF and SNAP receipt in previous twelve months, parent immigration status, English or non-English primary language in household, child assessed in Spanish, residence in urban area, region of US where family resides. Unmatched results weighted by survey and jackknife weights. Models for matched results estimated with (semiparametric) regression-adjusted propensity-score weights.

Table 1. 4: Effects of Head Start on Teacher Assessments of EF Skills in the Classroom

Teacher Assessment	Inhibitory Control		Attentional Focus	
	OLS	PSM	OLS	PSM
Reference care				
HS vs. Parental care (n ≈ 3,000)	-.028	-.037	.013	.010
HS vs. Relative/Non-relative care	-.076*	-.085*	.007	-.004
HS vs. Prekindergarten	-.073+	-.071+	-.098**	-.110**
HS vs. Center-based care	-.040	-.042	-.063*	-.060*
	*** p<.001 ** p<.01 * p<.05 + p<.10			

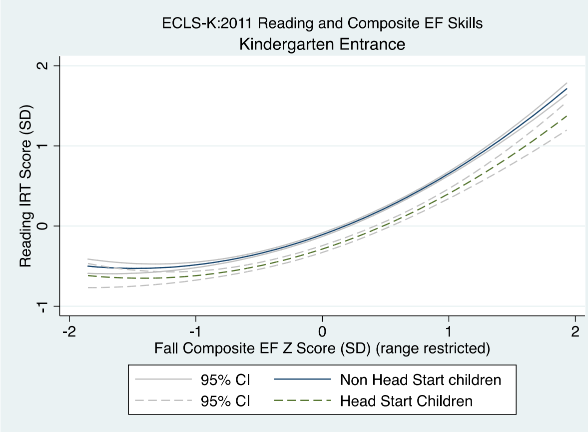
All models include: child's gender. race and ethnicity, low birthweight, age in months at assessment time, indicator disability diagnosis; maternal age at birth of first child, educational level, maternal employment status, indicator of mother's health if poor, family structure, number of siblings in family, poverty status, current WIC receipt, TANF and SNAP receipt in previous twelve months, parent immigration status, English or non-English primary language in household, child assessed in Spanish, residence in urban area, region of US where family resides. Unmatched results weighted by survey and jackknife weights. Models for matched results estimated with (semiparametric) regression-adjusted propensity-score weights.

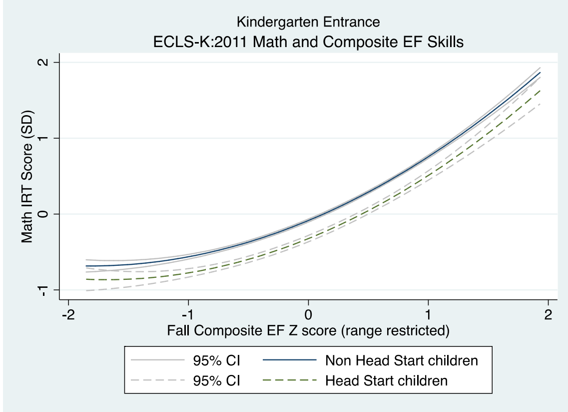
Table 1. 5: Effects of Head Start on Reading, Math, and Teacher Assessments

	Reading IRT		Math IRT		Internalizing problems		Externalizing problems		Approach to Learning	
	OLS	PSM	OLS	PSM	OLS	PSM	OLS	PSM	OLS	PSM
Reference care	M		M	M	M	M	M	M	M	M
HS vs. Parental care	.095***	.111**	.086**	.104**	-.090**	-.094*	.111**	.123***	.015	.017
HS vs. Relative/Non-relative care	.102**	.101**	.073*	.072*	-.051	-.053	.133***	.125**	.021	.022
HS vs. Prekindergarten	-.097**	-.090**	-.089**	-.092**	-.044	-.046	.027	-.013	-.085*	-.093**
HS vs. Center-based care	-.135***	-.132**	-.175***	-.170***	.001	.007	-.010	-.007	-.032	-.040
	All outcomes standardized (M=0, SD=1) *** p<.001 ** p<.01 * p<.05 + p<.10									

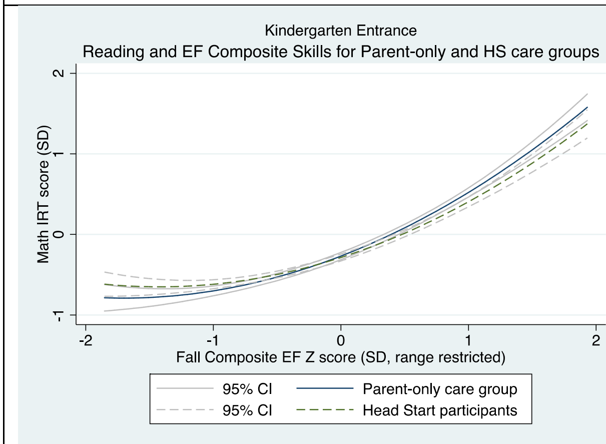
All models include: child's gender. race and ethnicity, low birthweight, age in months at assessment time, indicator disability diagnosis; maternal age at birth of first child, educational level, maternal employment status, indicator of mother's health if poor, family structure, number of siblings in family, poverty status, current WIC receipt, TANF and SNAP receipt in previous twelve months, parent immigration status, English or non-English primary language in household, child assessed in Spanish, residence in urban area, region of US where family resides. Unmatched results weighted by survey and jackknife weights. Models for matched results estimated with (semiparametric) regression-adjusted propensity-score weights.

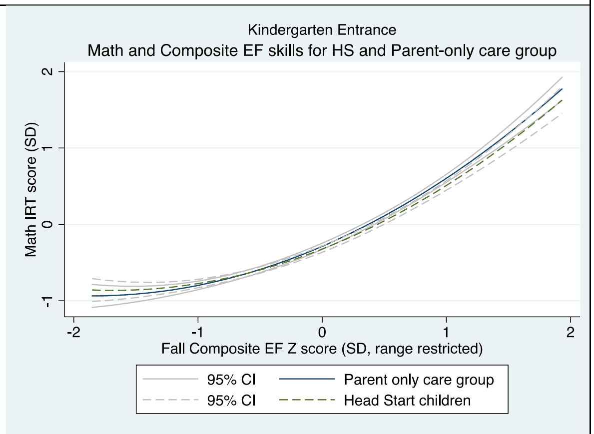
Supplementary Figures: Relationships Between EFs, Reading and Math at Kindergarten Entry



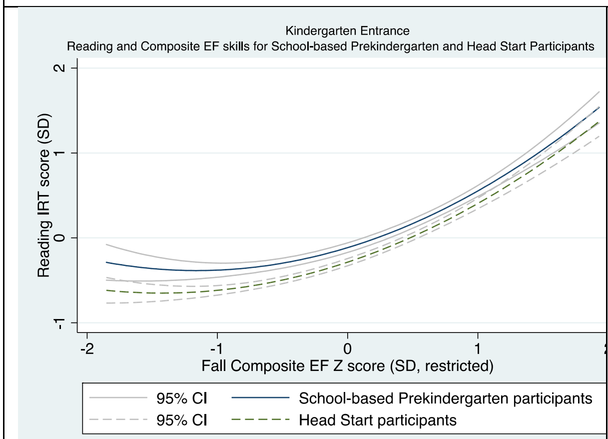


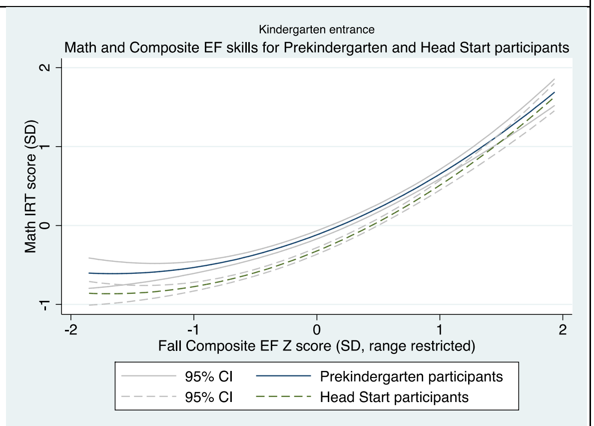
The figures above illustrate that HS children appear to have somewhat lower average scores in both reading and math compared to children in other care groups who attained the same composite EF scores, for much of the distribution of composite EF (between -2 SD and 2 SD).



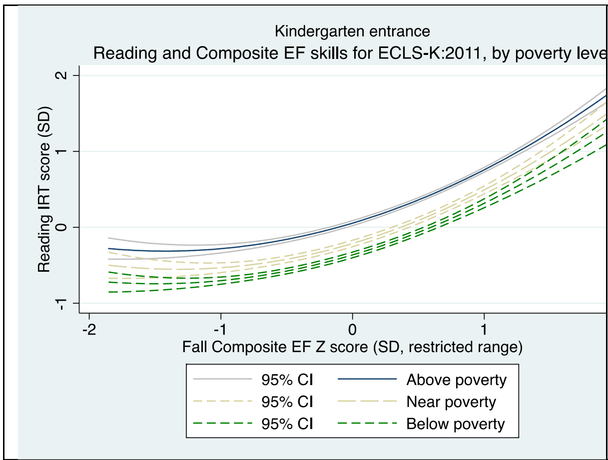


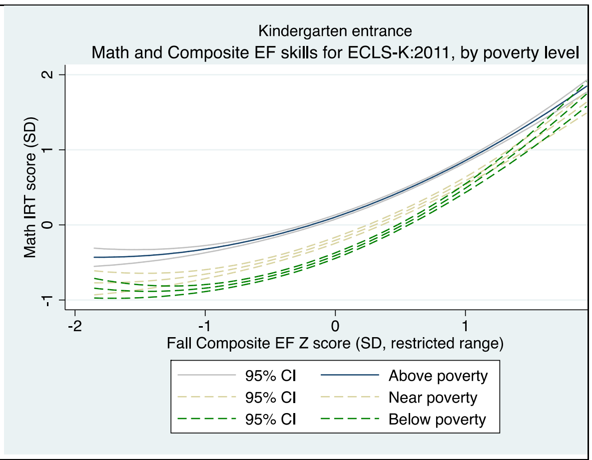
For children in the parent-only care group, the relationship of composite EF and math and reading scores is much more similar to that of the HS children.



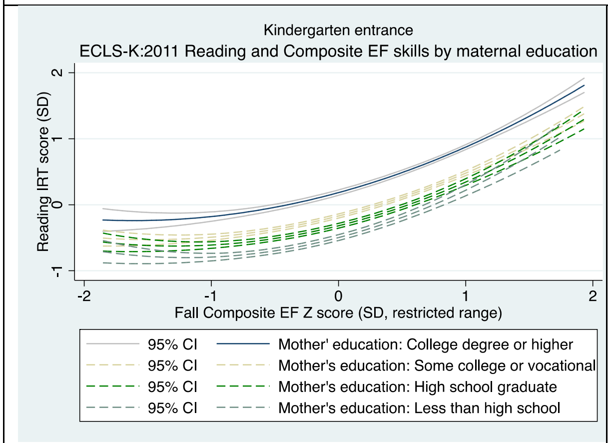


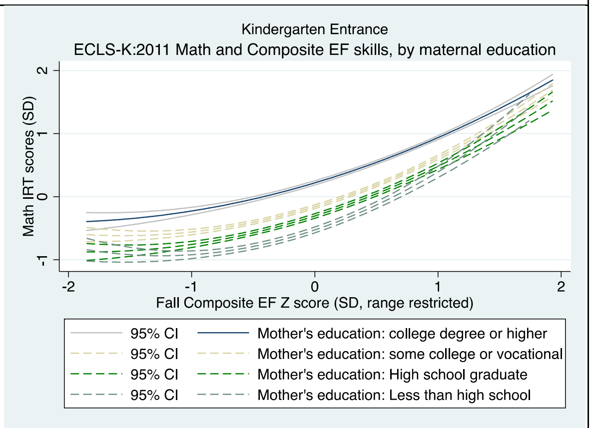
Many of the children who attended school-based prekindergarten who attained the same composite EF scores as children who attained HS have, on average, higher reading and math scores than the HS children.



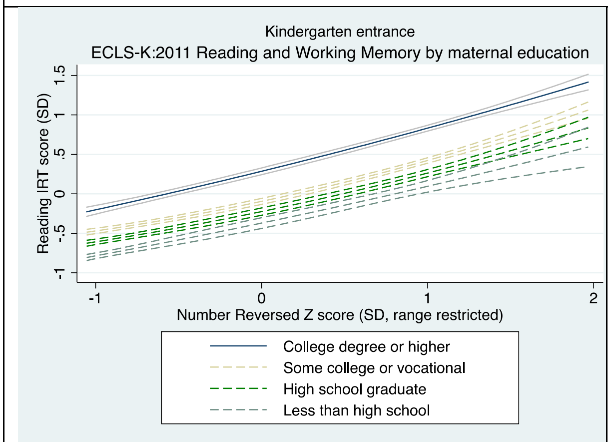


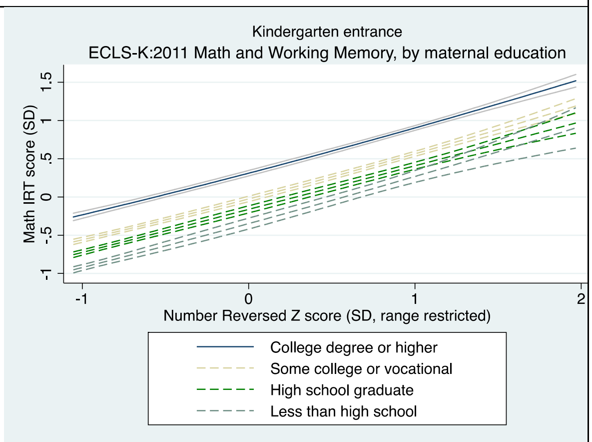
This figure shows disparate math and reading outcomes for three groups: those living above the poverty threshold (200% and above), those living near it (100% to 200%), and those living below it. Those living above poverty attain higher math and reading scores on average than the children in the other groups who have the same composite EF scores.





The relationship of composite EF to both reading and math for four groups defined by maternal education levels is provided above. The children of women who attained a college degree or better clearly attain higher reading and math scores than children whose mothers have lower levels of educational attainment, despite similar levels of composite EF.





The relationship of Working Memory (with scores ranging from -1SD to 2 SD) to both reading and math for four groups defined by maternal education levels is provided above. The children of mothers who attained a college degree or better have higher reading and math scores than those children with mothers with lower levels of educational attainment who scored similarly on WM.

Appendix

Appendix 1A: Characteristics of HS children not included in matching analysis

Because the "common support" option was used in matching children in alternative care groups who would provide sufficiently similar cases for comparison with the HS participants, some "treated" children were excluded from each analysis (as well as many children in the alternative care groups who were not suitably similar to the HS participants). The number and a brief description of the number and prevalent characteristics of a small group of HS participants who were not matched (and for whom the estimates provided here to do not apply) is presented here.

Alternative care group analysis	HS children not included in matched estimation.
Parental care only	Fewer than twenty black children (mostly boys) in single-parent families with mothers who worked full-time.
Informal care by relatives and non-relatives	Fewer than ten urban black or Hispanic children living below the poverty level; most living two in two-parent families and all receiving food stamps. Many low birthweight.
School-based pre-K	Fewer than twenty mostly black children, living in subpoverty families in urban households receiving food stamps, WIC, and TANF. Many in urban areas in the West and Northeast.
Center-based care	Fewer than ten black and Hispanic, many low birthweight. Many immigrant mothers very young at the age of first birth.

Appendix 1B: Supplementary Analyses by Gender

Effects of Head Start on Continuous Executive Function Outcomes, by Gender: Matching Estimation Only

Task Measure	Numbers Reversed		“Non-Zero” Num Rev		Standard DCCS		Color Score only		Advanced DCCS		Composite EF	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
Reference care												
HS vs. Parental care (n ≈ 3,000)	.013	-.018	-.010	-.057	.093*	.099+	-.003	.069	.084+	.053+	.068	.063
HS vs. Relative/Non-relative care	-.011	.031	-.027	-.005	.072	.065	-.073	-.004	.086	.002	.046	.041
HS vs. Prekindergarten	-.011	-.070**	.009	-.112	-.043	.077	-.104*	-.006	-.005	.002	-.023	-.078
HS vs. Center-based care	-.104*	-.143**	-.097	-.177**	.016	-.098*	.090	-.021	.020	-.124**	.004	-.165***

All outcomes standardized (M=0, SD=1)
*** p<.001 ** p<.01 * p<.05 + p<.10

All models include: child’s race and ethnicity, low or very low birthweight, age in months at assessment time, indicator disability diagnosis; maternal age at birth of first child, educational level, employment status, indicator of mother’s health if poor; family structure, number of siblings in family, poverty status, current WIC receipt, TANF and SNAP receipt in previous twelve months, parent immigration status, English or non-English primary language in household, child assessed in Spanish, residence in urban area, region of US where family resides. All within-gender subgroup effects were estimated with (semiparametric) regression-adjusted propensity-score weights, so that children were closely matched within gender for each care type.

Effects of Head Start on Reading, Math, and Teacher Assessments, by Gender: Matching Estimation Only

	Reading IRT		Math IRT		Inhibitory Control		Attentional Focus		Internalizing problems		Externalizing problems		Approach to Learning	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
Reference care	M	M	M	M	M	M	M	M	M	M	M	M	M	M
HS vs. Parental care	.135***	.090*	.133**	.076*	-.043	-.034	.001	.002	-.138**	-.047	.144**	.103*	.018	.022
HS vs. Rel./Non- rel.	.088*	.106*	.046	.010*	-.117*	-.062	-.030	.027	-.097	-.025	.156*	.100*	.002	.050
HS vs. Prek	-.040	-.140**	-.038	-.146**	-.099+	-.046	-.114*	-.082	-.058	.066	.051	-.058	-.116*	-.050
HS vs. Center Care	-.127**	-.139**	-.191**	-.144**	-.013	-.068	-.044	-.048	-.032	.053	-.022	-.007	-.010	-.051

All outcomes standardized (M=0, SD=1)
*** p<.001 ** p<.01 * p<.05 + p<.10

All models include: child’s race and ethnicity, low or very low birthweight, age in months at assessment time, indicator disability diagnosis; maternal age at birth of first child, educational level, employment status, indicator of mother’s health if poor; family structure, number of siblings in family, poverty status, current WIC receipt, TANF and SNAP receipt in previous twelve months, parent immigration status, English or non-English primary language in household, child assessed in Spanish, residence in urban area, region of US where family resides. All within-gender subgroup effects were estimated with (semiparametric) regression-adjusted propensity-score weights, so that children were closely matched within gender for each care type.

Appendix 1C: Descriptives by Care Group and Analysis of Binary "Threshold" EF Outcomes

Descriptive Statistics of Binary EF Outcomes by Care Arrangements, Unmatched Samples

Variable	Head Start (n≈1,950)	Pre-K (n≈1,500)	Center-Based Care (n≈ 5,550)	Relative/ Non-Rel. Care (n≈1,350)	Parental Care (n≈ 2,600)
Exceeding "0" in Numbers Reversed	.463	.605***	.723***	.519**	.514**
Proceeding to three digits in Numbers Reversed	.442	.585***	.706***	.513***	.501***
Proceeding to four digits on Numbers Reversed	.146	.234***	.310***	.168	.199***
Proceeding beyond "0" on Shape subtask in DCCS task	.870	.906**	.942***	.881	.872
Qualifying for Border subtask in DCCS	.784	.841***	.873***	.801	.781
Scoring Above 1 SD+ on Border subtask in DCCS	.171	.239***	.296***	.239***	.208**
	*** p<.001 ** p<.01 * p<.05 + p<.10				

Group means weighted by survey sample and jackknife weights. All sample sizes are rounded, in accordance with NCES guidelines, to the nearest 50 students.

Outcomes represent proportions of children in each group who accomplished each subtask or threshold.

Effects of Head Start on Executive Function "Thresholds" (Odds Ratios)

	Numbers Reversed Thresholds						DCCS Thresholds					
Task Measure	Achieve Positive Numbers Reversed		Proceed to 3-digits		Proceed to 4-digits		Score Above Zero in Shape task		Qualify for Border task		Achieve at least +1 SD on Border task	
	Unmatched	Matched	Unmatched	Matched	Unmatched	Matched	Unmatched	Matched	Unmatched	Matched	Unmatched	Matched
Reference care												
HS vs. Parental care	1.06	1.08	1.03	1.07	.892	.888	1.20	1.27**	1.21*	1.27*	1.00	1.07
HS vs. Relative/Non-rel	1.07	1.04	1.00	.972	1.02	1.04	1.32*	1.29	1.20+	1.18	.834+	.905
HS vs. Prekindergarten	.826*	.819*	.846*	.857+	.806*	.783*	.995	1.00	.962	1.00	.833+	.900
HS vs. Center-based care	.822**	.827**	.800**	.798**	.762**	.765**	.852	.786	.901	.883	.765**	.772**
	*** p<.001 ** p<.01 * p<.05 + p<.10											

All models include: child's gender. race and ethnicity, low birthweight, age in months at assessment time, indicator disability diagnosis; maternal age at birth of first child, educational level, maternal employment status, indicator of mother's health if poor, family structure, number of siblings in family, poverty status, current WIC receipt, TANF and SNAP receipt in previous twelve months, parent immigration status, English or non-English primary language in household, child assessed in Spanish, residence in urban area, region of US where family resides. Unmatched (logistic) results weighted by survey and jackknife weights. Models for matched results estimated with (semiparametric) regression-adjusted propensity-score weights.

VII. Paper 2: How Does Math Content Level in Kindergarten Affect Children With Different Early Care Experiences?

Introduction

In this paper, I further investigate disparities in the development of executive functions (EFs) and their relationship to academic learning within the framework of alternative care types in the year preceding kindergarten, with particular focus on children who attended Head Start (HS). Findings in paper #1 suggest that HS participants emerge from the program as learners with distinct challenges as they enter kindergarten, even in comparison with other disadvantaged children. Expenditures targeting such children after they attend HS do appear to extend and even augment the program's long-term benefits (Johnson and Jackson, 2017), and many teachers and schools are likely to focus more attention on helping disadvantaged kindergarteners to "catch up" to other children (Ansari and Pianta, 2018). However, socioeconomic disparities in EF skills at school entry appear to be driven largely by differing levels of parental education and home learning environments established by parents (Conway, Waldfogel, and Wang, 2018; Conway, Waldfogel, and Wang, 2019), factors that do not radically change because of HS participation and thus continue to influence children's development as they move through school. Disparities in parental education levels also appear to drive large gaps in other cognitive outcomes for U.S. children at kindergarten, which in turn account for as much as 70% of continuing, and generally widening, achievement gaps through at least age eleven (Bradbury, Corak, Waldfogel, and Washbrook, 2015). In examining the extent to which early school experiences help to reduce socioeconomic gaps in achievement in the U.S., it is important to look closely at growth rates in EF skills in the context of the early academic achievement of disadvantaged children, alongside corresponding growth rates for more advantaged children. As EFs are important to children's functioning in the transition to school (Connors, Ponitz, and McClelland, 2010), and particularly since early cognitive gains resulting from early childhood education (ECE) sometimes diminish or disappear in the early years of elementary school (Barnett, 2011), it is critical to shed more light on how early school experiences shape children's continued development in these areas.

Aside from evaluation of tailored interventions delivered to specific HS classrooms, there has been very little examination of the development of EFs and related outcomes in the early school years for HS participants in comparison to children who experienced other forms of early care. While considerable scholarship is underway to explore school- and classroom-based practices in support of low-income children in their first few years of school and beyond, little work has investigated *whether the effects of such practices vary for particular ECE groups*, including HS participants. In this paper, I first compare growth rates of HS participants from the fall of kindergarten through second grade against those of four groups of children who experienced other types of care in the year preceding kindergarten. I investigate working memory and cognitive flexibility, as well as the related outcomes of math and reading, establishing monthly growth rates both during the kindergarten year and the subsequent period (first and second grades) for each care group. Since HS participants enter school with lower EF skills on average than most children, and in view of recent research pointing to rapid growth in EFs during kindergarten for most such children (Ready and Reid, 2019), my first question #1) is: *Once in school, do HS participants experience faster growth in EFs in comparison with children who received other types of early care, and is their growth reflected in a parallel surge in academic achievement*? Particularly in view of the strong association between working memory at the start of kindergarten and third grade achievement (Nguyen and Duncan, 2019), and the lack of a positive HS effect on working memory seen in paper #1, it is important to know more about growth rates for this outcome among HS attendees after they enter school. I shall also examine how growth rates of EFs relate to the related outcomes of math and reading growth rates, particularly for HS participants.

Next, I examine the role of kindergarten mathematics content in the growth of math skills, EFs, and reading. Following investigation of math content in kindergarten (Engel, Claessens, and Finch, 2013; Engel, Claessens, Watts, and Farkas, 2016), I shall investigate questions #2 and #3: *#2) Does exposure to more advanced math content in kindergarten appear to support more math learning for HS to the same extent as it does for most other children? #3) Does exposure to more basic math content (such as counting) negatively affect these children's math learning?* In view of evidence that superior math instruction can support EF skills (Clements, Sarama, and Germeroth, 2016), I shall investigate question *#4): Does exposure to more basic or higher math content appear to EF outcomes, in particular working memory?* In view of the strong influence early math abilities exert on cognitive scores in reading and other language-related outcomes (Duncan, Dowsett, Claessens, Magnuson, Huston, Klebanov, Pagani, Feinstein, Engel, and Brooks-Gunn, 2007; Nyugen, 2017), I shall also investigate question #5): *Does exposure to higher math content positively affect reading outcomes?* In the context of the convergence of outcomes for young children after ECE, it is also important to ask: *#6): Do positive or negative effects of mathematics content on any outcomes persist, for any group of children as defined by early care type, through first and second grades?*

Literature Review

Growth rates and development of children's executive functions

In multilevel analyses of executive function (EF) development using the ECLS-K:2011, children with the lowest initial levels of EF skills at kindergarten entrance experience higher average levels of growth in this area during kindergarten and first grade than children who were initially medium- or high-skilled in EFs (Ready and Reid, 2019). The authors also find, however, that schools' composition influences this development as well, for all groups. Regardless of their initial EF skills at school entry, children demonstrate average greater EF gains in schools with higher proportions of high-SES students, and smaller gains in schools with higher proportions of black and Hispanic students. Given findings from paper #1 demonstrating much lower average ratings on EFs for HS participants (roughly one-third of a standard deviation below the cohort mean for composite EFs), the implications of the longitudinal findings for these and other disadvantaged children are dual: the first is that many of them may experience higher-than-average growth rates as they enter school; but the second is that these rates can be negatively affected by attendance at high-poverty schools.

The EF literature for young children's development informs some expectations. In the typical patterns, cognitive flexibility (or "shifting" or "switching") draws upon the earlier emergence of working memory skills and it tends to become apparent in children's functioning slightly later in early childhood than working memory. While children may experience a surge in cognitive flexibility in the early school period, especially if they are scaffolded to engage with more complex paradigms and to switch between aspects of materials they are working with or to follow new sets of rules (Diamond, 2013), examination of seven-year-olds mathematics abilities suggests that difficulties with appropriate switching (from addition to subtraction for example) may result from weak underlying working memory skills (Bull and Scerif, 2001). Some higher-level academic tasks, such as reading comprehension, particularly require strength in cognitive flexibility beginning in middle childhood (Kieffer, Vukovic and Berry, 2014), so that a deficit in this area, in the absence of intervention, may negatively affect achievement more as children move into later years of schooling (Cartwright, Coppage, Lane, Singleton, Marshall, Bentivegna, 2017). Working memory skills have an especially strong relationship to academic achievement (Bull and Lee, 2014; Nguyen and Duncan, 2019), and their growth typically continues through the early school years and even through adolescence (Luna, 2009). Also of importance is evidence suggesting that the process of *acquiring* early math skills on certain tasks in the early school years may actually be critical in the development of children's EFs (Ansari, Garcia, Lucas, Harmon, and Dhital, 2005); conversely, once processes become more automatic and performance is "optimal," EFs are not, generally speaking, required for the same math tasks (Diamond, 2013). This suggests that any school activity that stimulates growth in children's EFs could be especially valuable for them, in the short- and long-term.

The persistence of gains in academic measures after HS participation

It is helpful to know that children who have participated in HS before attending public schools funded by higher expenditure levels receive additive benefits (exceeding those from either HS or the better-funded schools alone) that extend into adult life outcomes (Johnson and Jackson, 2017). However, other research on the effects of compensatory funding underscores that it can be quite difficult to trace positive effects in students' short- or middle-term academic outcomes from measures of federal or state funding (Kainz, 2019). Such research also can tell us little about what specific aspects of students' school experiences can improve their educational outcomes or, by extension, how compensatory funding ought to be directed.

Importantly, several previous studies that found positive reading and math gains of Head Start (HS) for children (in comparison with children who did not attend center-based care) also provided evidence that these gains persist into at least first grade, when later outcomes for the same comparison groups are measured against each other. Zhai, Brooks-Gunn, and Waldfogel

(2014) highlight significantly stronger performance through first grade by HS participants on measures of receptive vocabulary ($d=.25$, $p<.05$), letter-word identification ($d=.23$, $p<.05$), and mathematical problem-solving ($d=.30$, $p<.05$). Feller, Grindal, Miratrix and Page (2016) estimate a .10 SD gain in vocabulary skills in first grade for HS participants who would, in the absence of experimental assignment in the HSIS, received only family care. In a study without reference to care types of the control children, Bitler, Hoynes, and Domina (2014) find a significant gain in vocabulary skills (averaging from .38 to .58 SD on the PPVT) that persists into first grade for Spanish-speaking HS participants in the lower half of the outcome distribution, in comparison with outcomes of similar children – regardless of their counterfactual care type.

These are promising indications that the investment cost of the program (more than \$8 to 9 billion annually) can diminish achievement gaps beyond kindergarten entrance for some of the most disadvantaged children in the U.S. However, the gains noted are small, and in view of the average poor quality of schools which HS children frequently attend (Duncan and Magnuson, 2013), much remains to be explored in terms of the specific practices required to sustain or increase growth. Interventional research supports that for optimal results, high-quality early care must be followed by sufficiently high-quality schooling to in order to maintain advantages already acquired and to further “catch up” to others (Zhai, Raver, and Jones, 2012). In particular, research in this area recently focuses on issues of alignment of instructional content and pedagogical approaches across early care and school environments (Mashburn and Yelverton, 2019). Educators emphasize the value of carefully planned, sequential curricula (Stipek, Clements, Coburn, Franke, Farran, 2017), sometimes based on theories of learning that involve subject-specific trajectories, or “empirically supported developmental progressions” (Clements and Sarama, 2009). Related to these issues is growing awareness of the importance of differentiation of instruction for children who did and did not attend HS, pre-K, or other ECE programs (Gormley, Phillips, and Anderson 2017), and renewed interest in the practices of readiness assessments and ability grouping.

Instructional practices and interventions in the K-3 years

That the first few years of formal schooling provide appropriate cognitive stimulation, for those who have attended ECE as well as those who did not and are most in need of "catch-up," is of particular concern (Claessen, Engels, Curran, 2014; Brooks-Gunn, Markman-Pithers, Rouse, 2016; Ansari and Pianta, 2018). Recent research, using the ECLS-K data and other sources, tests a number of practices in order to identify which ones effectively extend ECE program benefits. These specific practices in schools and classrooms include transition practices (Schulting, Malone and Dodge, 2005), readiness assessments (Little, Cohen-Vogel, and Curran, 2016), school climate (Ansari and Pianta, 2018), direct instruction and other classroom formats (Morgan, Farkas, and Maczuga, 2015; Ansari and Purtell, 2018), and mathematics interventions (Clements, Sarama, Wolfe and Spitler, 2013). Some studies report no positive effects, in contrast to expectations, while in other cases, positive findings emerge. While researchers frequently report larger effect sizes for children from low-SES backgrounds, no studies appear to investigate differential effects by early care type in the context of persistence of ECE gains. Questions of additional interest that remain unaddressed include a) whether children's EF skills increase in consequence of these practices, and b) whether potential growth in EFs is a factor in any boosts to academic achievement. The answers to such questions could be important, since each type of early care experience likely produces distinct types of learners, even from similar backgrounds. In the case of HS participants, paper #1 demonstrates that their average advantages in reading and math over children who experienced no center-based care are notably smaller than those of children who attended other kinds of center-based care or school-based pre-k. It could also be important that these rather slight academic gains for HS participants are unsupported, in their case, by larger average gains in working memory among children who attended other forms of center-based care, including school-based public pre-k.

Alignment of kindergarten math curriculum; potential effects of improved math instruction

Using the ECLS-K's teacher survey data and assessments of math proficiency for kindergarteners entering school in 1998, Engel, Claessens, and Finch (2013) highlight a "mis-alignment" of math content as it is most frequently taught to kindergarten classes, meaning that children spend most classroom math learning time on rudimentary content (primarily, counting and identifying shapes) they have already mastered. This study tests whether most students benefit from "less constraint" on the content of math instruction in kindergarten, since they have had already learned concepts such as counting, often in preschools. To expose them to higher levels of content would be to "align" instruction in a way that enables their achievement, continuing the ECE investments of their preschool experiences.

The analysis of math IRT scores demonstrates that more lessons on "advanced" content during kindergarten (including problems involving place, money, and the addition and subtraction of small numbers) predicts greater achievement by the end of kindergarten for most students, while more lessons on the basic content is associated with weaker achievement (Engel, ibid.). Only a few students in this earlier cohort, those who entered kindergarten with very low math competency, appear to have improved math achievement as a result of more instructional lessons on basic content such as counting. More recently, Engel, Claessens, Watts, and Farkas (2016) followed up by comparing the two ECLS-K cohorts to find that overemphasis on basic math content in classrooms persists for the children entering school in 2011. Again in this second paper, analysis underscores that for the majority of children in the more recent cohort there is an association between higher math achievement in the spring of kindergarten and more lessons on advanced math content; of great concern is that on average, receiving more frequent lessons on basic content is a significant predictor of lower math achievement.

While acknowledging the lack of other measures relating to mathematics instruction in their analysis, these authors point out that a shift to more appropriately aligned math content in kindergarten is a relatively low-cost intervention, in contrast to many others. The reported effect sizes are small, yet highly significant; for a standard deviation increase in “Addition and subtraction” per month, ES=.046 points, $p<.001$and for a standard deviation increase in lessons on “Basic counting and shapes” per month, ES=-.023 points, $p<.001$. The studies do not examine whether the gains persist into subsequent years, nor does the second study present any subgroup analyses for differential effects, both of which are especially important for disadvantaged learners such as HS participants. The relevance of this area of inquiry for particularly disadvantaged children (and their EF development) is that clearer understanding is required around this practice, since they enter school with quite different levels of preparation for academic skills. Additional instruction on more advanced math content in kindergarten might be helpful to achievement, or it may be that many such children could receive benefits from additional lessons on basic math content. Either strategy could be a critically timed “skills-building” intervention for disadvantaged children (Bailey, Duncan, Odgers and Yu, 2017). Even if findings are consistent with earlier studies, effect sizes could be notably different for HS participants than for more advantaged children, and that is also significant information.

Perhaps unsurprisingly, socioeconomic math gaps appear to stem largely from initial math proficiency at the start of kindergarten and home learning environments (Galindo and

Sonnenschein, 2015), echoing disparities in EFs. Evidence underscores the importance of both inhibitory control and working memory in supporting children's early math abilities (Harvey and Miller, 2017). While researchers studying math content examine its effects on only math achievement, others maintain strong focus on the potential for high-quality, "cognitively demanding" mathematics curricula to positively affect other outcomes in early childhood as well, citing in particular a bi-directional relationship of mathematics learning and EF development (Clements, Sarama, and Germeroth, 2016). Early mathematics learning is believed to strengthen more general, innate cognitive abilities in very young children, such as EFs (Clements and Sarama 2009), and high-quality efforts in support of the math skills of disadvantaged students have resulted in improved EFs as well (Clements and Sarama, 2013). At least one study has found that in comparison to several other measures including early literacy, mathematics ability at school entry is a stronger predictor of later reading achievement (Duncan et al., 2007). However, to my knowledge, the effects of advanced math content in kindergarten on outcomes other than math, in particular for disadvantaged students, have not yet been investigated, although instructional practices in math clearly can affect disadvantaged students' outcomes in ways very differently than they do more advantaged children (Morgan, Farkas, and Maczuga, 2015). The question of whether a low-cost intervention, such as shifting instructional time to more advanced math content, could produce improvements on multiple outcomes for HS participants merits investigation.

Purpose of This Paper

When examining the continued effects of HS participation in the years after kindergarten entrance, it is important to consider how practices and resources at the schools children attend in those years may interact with earlier care arrangements available to children's families. This paper will provide a better understanding of how HS participants' growth rates in EFs, math, and reading differ from those of children who experienced other care types in the year before kindergarten. More specifically, I shall investigate whether disadvantaged children are affected differentially by learning more basic or more advanced math content in kindergarten than the majority of students cited in the "mathematics content" literature, and whether any effects of such instruction persist beyond the kindergarten year. Similar to previous literature, I shall examine effects of math content net of child, family, teacher, and school characteristics. Unlike earlier analyses in this area, I shall model growth rates, with an eye to persistence/convergence of effects. A multilevel framework will account for students' progress over time and the clustering of ECLS-K children within schools (Singer and Willett, 2003).

Data and Methods

Analytic sample

From the cohort of the ECLS-K:2011 study produced by the National Center for Educational Statistics (NCES), I begin with the same analytic sample I used for paper #1, including 12,900 children in 850 schools, who were first-time kindergarteners in the fall of 2010 and for whom there is non-missing information on age, gender, race/ethnicity, and parent survey information on early care arrangements in the year before kindergarten[6]. Students were also selected on the basis of non-missing information for the first wave on all four outcomes. This

[6] In accordance with NCES reporting rules, all sample sizes were rounded to the nearest 50 children.

second paper will draw from survey data, including interview responses conducted with parents and teachers, and direct assessments of the children's cognitive abilities in both fall and spring each year from kindergarten entry through the spring of second grade, with special reference to the type of care they received in the year before starting school as recorded in parent survey data collected during the fall and spring kindergarten waves. Early care arrangements were designated through the same procedures used in paper #1. For initial analysis, comparing growth curves of HS participants to those of other care groups without reference to math content levels, I employ the full analytic sample. For analyses of differential effects of math content level, I estimate separately for each group of children, as defined by early care type.

Since previous study of children's EFs and academic achievement shows disparate growth rates for kindergarten and subsequent time periods (Votruba-Drzal, Li-Grining, and Maldonado-Carreño, 2008; Ready and Reid, 2019), I use models employing a multilevel piece-wise growth curve framework, enabling separate estimation for growth rates that describe development during a) the kindergarten year and b) the subsequent two-year period, until the end of second grade. In the multilevel framework, each child's outcomes over time (as defined by the waves when they were assessed) are nested within each child, and children are nested within schools that they attend.

Missing data was accounted for through multiple imputation, as in paper #1, but with models including variables needed to account for school and teacher characteristics. Additional school and teacher characteristics had rates of missing data ranging from 5.7% for highest teacher education level to 13.7% for the total percentage of English Language Learners in each school's student population. In order to retain the full analytic sample of 12,900, I estimated missing data with multiple imputation using chained equations, implementing predictive mean matching as needed, to create ten complete datasets with imputed values for the missing covariate predictors. (As part of the imputation modelling, variables were extensively tested using recommended diagnostics (Eddings and Marchenko, 2012)). In the analysis of outcomes, coefficients and standard errors were estimated for each imputed dataset and combined these using standard procedures to adjust for uncertainty within and between imputations (Rubin, 1976; Rubin, 1987).

Outcome measures

In contrast to paper #1, this paper's focus is on how children's outcomes change over time; its analyses investigate growth rates over time instead of relative growth across groups. Therefore, instead of standardizing outcomes as I did for paper #1, I use measures recommended by the NCES for this type of analysis (Tourangeau, Nord, Wallner-Allen, Vaden-Kiernan, Blaker, Najarian, Mulligan, 2017; Ready and Reid, 2019).

Executive functions

In this paper I continued using the formal assessments of children's cognitive flexibility (rating children's performance on the Dimensional Card Change Sort task) and working memory skills (measured using the Numbers Reversed task) (Tourangeau, Nord, Wallner-Allen, Vaden-Kiernan, Blaker, Najarian, Mulligan, 2017). In kindergarten and first grade (waves 1 through 4), children's cognitive flexibility was measured by a table-top version of the Dimensional Card Change Sort task (Zelazo, 2006). In second grade, a computerized version of the task was implemented, and so there are no measures of this outcome for the fifth and sixth waves compatible for the estimation of growth across time with the earlier, non-computerized measures. For this outcome only, I am able to include only four waves in my analysis.

Measures provided by the ECLS-K:2011 for children's performance on the first four waves of this task include a pre-switch score (representing only the number of cards correctly sorted by color), a post-switch score (representing the number of cards correctly sorted by shape), a border score (representing the number of cards correctly sorted by the presence or absence of a border on the card), and a combined score each representing the total number of correct responses for the three previous scores. Because most children have proceeded to the Border task by the end of first grade, and following Ready and Reid (2019) in other longitudinal work with this outcome, I used the combined score in its raw metric for each of the four non-computerized waves; these scores are measured by correct responses and range from 0 to 18.

As in paper #1, children's working memory was measured by a backward digit span task across all six tasks, the Numbers Reversed task of the Woodcock-Johnson III Test of Cognitive Abilities (Woodcock, McGrew, and Mather, 2001). For each assessment, children were asked to repeat in correct reverse order a series of numbers read aloud to them, beginning with five series of two-digit numbers, and increasing through progressively larger series of numbers, until they either answered three consecutive series incorrectly or finished responding to the series of eight-digit numbers, at which point the assessment stops.

The ECLS-K:2011 provides five scores in measurement of children's performance on this task including, an age standard score, a grade standard score, an age percentile score, a grade percentile score, and a W-ability score (based on the application of a Rausch model) that represents both a child's ability and the difficulty of tasks measured. For cross-sectional analyses, the NCES recommends the use of one of the first four scores (Tourangeau, et al., 2017). The W-ability score, on the other hand, is useful for the measurement of growth in longitudinal studies. It is based on a common interval scale, such that an increase of a certain number points always represents the same amount of growth, anywhere on the scale. Rather than standardizing scores (with m=0, SD=1) as I did in paper #1, I use the W-ability score on this measure across six waves for all analyses. These scores range from 393 to 693.

Reading and math skills

ECLS-K staff administered IRT assessments in both reading and math beginning in the fall of kindergarten and continuing through all six waves, and I used the scale scores at all time points for the analytic sample. These assessments provide ideal for measures for a longitudinal analysis, since they are measured on a consistent metric reflecting growth over time (Singer and Willett, 2003). Reading IRT scores range from 0-120 and math IRT scores range from 0-113.

Math content level:

Following Engel, Claessens, and Finch (2013) and Engel, Claessens, Watts, and Farkas (2016), I created four numeric "content measures" from data from teacher surveys (from wave 2). Each content measure variable ranges from 0 to 20 and represents the number of lessons on material from that content level per month. They were calculated from teachers' responses to surveys in the spring of kindergarten, when teachers were asked how often each month they taught certain mathematical topics. Earlier studies of math content operationalized the teachers' answers as variables representing the number of lessons each month on which kindergarteners were taught material from each of four content levels, listed here in increasing difficulty and labelled by the authors: "Basic counting and shapes," "Patterns and measurement," "Place value and currency," and "Addition and subtraction." For a listing of specific survey measures comprising each content measure, as well as how variables for each content level were coded using teachers' responses, see Appendix A. Following the earlier papers on math content, I also included a control for how many minutes of math instruction in total students received per month (ranging from 0 to 900). In contrast to the earlier papers, which did not model the children's growth curves, I did not standardize the variables for math content but instead used the raw metric math content level variables in estimation for separate groups of children as defined by early care types. Results here therefore should be interpreted as associations with *additional lessons*, rather than with a standard deviation increase of time on a particular math content level.

Child and family predictors:

As in paper #1, the ECLS-K provided rich measures of the characteristics of children and families, including measures of disadvantage that affect children's early cognitive abilities. These included each child's gender, race/ethnicity, and an indicator of low birthweight. Family characteristics included maternal employment, maternal education, the mother's age at the first birth of her child, an indicator variable for the self-reporting of poor maternal health, whether the family was living either below the poverty threshold, near poverty (between 100% and 199% of the threshold), or above poverty (200% or above the threshold), U.S. region, an indicator for single-parent families, an indicator for having a parent born outside of the U.S., and one for a non-English home language. I also included three indicators for receipt of social aid programs, since these can be predictive of children's cognitive outcomes: current participation in the WIC nutritional program, participation in the last twelve months in the SNAP (food stamp) program, and participation in the last twelve months in the TANF (cash transfer) program. I included an indicator measuring "1" if the child was assessed in Spanish in the first wave of kindergarten.[7] In order to adjust for children's relative maturity and testing experience, each child's age at the time of assessment is included in all analyses; each model includes an indicator reading "1" for the month of each child's first assessment in the fall of kindergarten, since children who are assessed

[7] Fewer than 2% of the total analytic sample required assessment in Spanish in the first wave; the number of children assessed in this way diminished rapidly and dramatically in subsequent waves.

earlier in the fall generally attain significantly lower scores than children who are tested after they have had time to acclimate to their school environment.

School level predictors, teacher characteristics

Models here also include measures that control for aspects of children's school experiences, including an indicator for full-day kindergarten, urban location of school, private school, percentage of school's student body that are English Language Learners (ELL), and the percentage of school's student body eligible for free or reduced lunch and school 79odelled79. Teachers' years experience and their educational attainment level (either Less than Bachelor's, Bachelor's Degree, Master's or Professional Degree) were also included as controls, as these have been shown to affect children's achievement.

Analytic approach:

Throughout data collection for the ECLS-K:2011, as students were assessed in fall and spring of each year, it was not possible to assess all of them in the same month of each round; fortunately the month of each assessment was reliably recorded along with the score of each child's assessment. To account for the variation in the amount of time between assessments for each student, I created variables measuring the number of months between assessments, which were then used in separate estimation of monthly growth for two distinct time periods. This approach, a piece-wise growth-curve framework (Singer and Willett, 2003), enabled estimation of separate trajectories of monthly growth rates during a) the kindergarten year, in which Efs develop especially rapidly for most disadvantaged children, and b) the period including first and second grade. Other work tracing the effects of specific kindergarten experiences on children's outcomes has employed a similar framework (Votruba-Drzal, Li-Grining, Maldonado-Carreño, 2008) to investigate discrepancies between growth rates during the kindergarten year from those in subsequent years. It is a useful tool for the examination of convergence in outcomes subsequent to early intervention. Each child's scores are nested within their individual learning trajectory, comprised of their initial status at kindergarten entry, their growth rate during kindergarten, and their monthly growth rate during first and second grade (first grade only for DCCS scores); the children are then nested within schools.

In order to first compare the rates at which the outcomes of children grouped by different care groups develop in their earliest school years, I first fit a set of relatively simple model including time periods, care groups, and interactions of each time period with each care group. Subsequent modelling for associations of growth rates with math content levels were fit separately for each group of children as defined by care type.

The models in simplified form follow here:

First-level (or measurement level):

$Y_{tij} = \pi_{0ij} + \pi_{1ij}TIME1 + \pi_{2ij}TIME2 + \epsilon_{tij}$

Child-level:

$\pi_{0ij} = \beta_{00j} + \beta_{01j}(C_{ij}) + \beta_{02j}(M_{ij}) + \beta_{03j}(F_{ij}) + \beta_{04j}(X_{ij}) + \beta_{05j}(M_{ij}) + r_{ij}$

$\pi_{1ij} = \beta_{10j} + \beta_{11j}(C_{ij}) + \beta_{12j}(M_{ij}) + \beta_{13j}(F_{ij}) + \beta_{14j}(X_{ij}) + \beta_{15j}(M_{ij}) + r_{ij}$

$\pi_{2ij} = \beta_{20j} + \beta_{21j}(C_{ij}) + \beta_{22j}(M_{ij}) + \beta_{23j}(F_{ij}) + \beta_{24j}(X_{ij}) + \beta_{25j}(M_{ij}) + r_{ij}$

School-level:

$\beta_{00j} = \gamma_{000} + \gamma_{001}S_j + u_{ooj}$

$\beta_{10j} = \gamma_{100} + \gamma_{001}S_j + u_{10j}$

$\beta_{20j} = \gamma_{200} + \gamma_{001}S_j + u_{20j}$

Y_{tij} is the growth of child I at time t in school j 80odelled as a function of the initial level of growth at school entry for child I (π_{0ij}), their monthly growth rate between fall and spring of kindergarten (π_{1ij}), and their monthly growth between spring of kindergarten and spring of second grade(π_{2ij}). (The variables TIME1 and TIME2 provide the number of months between assessments for each child.) Additionally, π_{0ij} is the initial score of child ij at the start of kindergarten, β_{00j} is the mean initial status at the school; C_{ij} represents the type of care the child experienced in the year preceding kindergarten; M_{ij} represents a dummy for the month of the child's first assessment in fall of kindergarten; F_{ij} represents an indicator of whether the child attended full-time kindergarten; X_{ij} represents a vector of child and family characteristics; M_{ij} represents the set of variables describing math instructional content; $r_{ij}$is the random effect associated with the kindergarten learning rate for child I at school j. As indicated above, β_{00j} is the mean initial status of the outcome at school j. β_{10j} is the average kindergarten monthly learning rate in the school. γ_{000} is the school-average mean initial status for the sample. $S_j$represents a vector of school characteristics included in the model; u_{ooj} represents the initial status error associated with school j; γ_{100} is the mean school-average kindergarten learning rate for the sample.

Findings

Descriptives

Table 1 provides descriptive statistics across the five ECE groups, providing means for child, family, teacher, and school characteristics included in models here, as well as the group means for four kindergarten math content levels as well as children's outcomes at each wave.

As seen in paper #1, HS participants in this sample begin kindergarten as a significantly more disadvantaged group than the other groups, on every measure including low birthweight, maternal education, single-parent household status, and benefit receipt. Particularly striking is that almost 47% of HS participants live in a household below the poverty level; in comparison roughly 38% of children who received exclusively parental care live at that level, and 30% of children who received informal care from relatives or non-relatives do so. A slightly higher proportion of children receiving only parental care (38.5%) have at least one parent born outside of the U.S. in comparison to HS participants (35.8%), but this difference is not significant.

HS participants differ significantly in the characteristics of their schools and teachers as well. The majority of these students attend public schools (95.4%), with the highest proportions of English-language-learning (ELL) students (17.8%) in comparison to school attended by other care groups (followed by children who experienced only parental care, at 17.6%). Schools that HS participants attend are statistically the likeliest to be located in urban areas (32.1%) in comparison with schools attended by children from other care groups. Student populations at these schools also have the highest percentage of students who qualify for either free or reduced-price lunches (66.4%).

Teachers' years of experience and teacher education are also significantly different across care groups. Teachers of HS participants have on average 14.2 years of experience, in comparison to 15.3 years for teachers of the most advantaged group of children, those who attended center-based care. Interestingly, teachers of HS participants are the most likely to have a master's or advanced degree (47.2%).

Interesting differences are seen among the groups' mathematics instruction, according to second-wave teacher surveys. HS participants receive the greatest average number of minutes of mathematics instruction, statistically, at 376 minutes/month, compared to the lowest figure for all groups, 327 for children who attended center-based care. They also receive the greatest average amount of "Level 1: Basic counting and shapes lessons per month" (11.7), with the exception of the group of children who received only parental care in the year preceding kindergarten (11.8).

Perhaps in recognition of overall advantages in preparation from the care they received before kindergarten, teachers reported providing children who attended center-based care an average of just 10.8 lessons per month at this content level.

Analysis

Note on interpreting results: As measures in this paper were not standardized (in contrast to paper #1), coefficient estimates in the Tables of this paper refer to actual points of student assessments. Where they describe growth curves, coefficients refer to a *monthly* growth rate within a time period, either during kindergarten or during the period between the spring of kindergarten and the spring of second grade. To describe associations involving math content levels is to describe the relationship between an outcome (in points) and a single lesson relating to the content level each month.

Tables 2 and 3 provide growth rates for each ECE group on the four outcomes, unadjusted for math content levels or other predictors. During kindergarten, the average growth rates of HS participants on Numbers Reversed (measuring working memory for this cohort) and the DCCS task (measuring cognitive flexibility) are both significantly higher (3.08 and .184, respectively) than those for children who attended either pre-k in schools or other center-based care, while remaining statistically quite similar to growth rates of children who did not receive center-based care in the year before kindergarten. Given the low initial levels on these measures for HS participants, this is consistent evidence with other findings that school attendance in the critical kindergarten year helps to boost the EF skills of disadvantaged children in order to "catch up" to other children (Ready and Reid, 2019). However, in the next period (from the end of kindergarten through the end of second grade for Numbers Reversed, and through first grade for the DCCS) monthly growth rates for HS children decrease and become much more similar to those of most other groups. They remain significantly steeper (by just .2 points per month) on working memory than children who attended center-based care. On cognitive flexibility, however, HS participants' monthly growth rates are the lowest of any other group of children, with a slight significant negative difference from children who received only parental care. Absolute levels for both measures on Table 1 show that, despite their surge in kindergarten, HS participants end up with the lowest average levels on both EFs of all groups, both at the end of second grade. It should be noted that average growth rates reported in Table 2 for Numbers Reversed among HS participants during kindergarten (3.08 points) fall well below rates (in Ready and Reid, 2019) for initially low-skilled children (4.40 points), and are quite close to those for medium-skilled children (2.97), despite the initial low levels among HS participants. Similarly, the growth rates reported here for the DCCS task for HS participants during kindergarten (.184 points) fall well below those reported in Ready and Reid (2019) for initially low-skilled children (.59 points). These discrepancies accurately reflect that not all HS children would fall in the lowest group (as defined by Ready and Reid, 2019) in terms of their initial EF skills, so it is unsurprising that their growth rates on these measures fall below levels reported for that fastest-developing children; nonetheless the discrepancies – that HS participants' growth rates are not steeper – *may* also suggest short-comings in how their learning environments in school are supporting their development.

Monthly growth rates for HS participants in math, presented in Table 3, indicate that during kindergarten these children's abilities improve at roughly the same rate as that of children who attended either school-based pre-k or center-based care. This is unfortunate, considering the significantly lower baseline math scores of HS children (425, in comparison to 434 for pre-k children and 442 for center-based participants), and their steeper growth rates in EFs in comparison to the other two groups of children who attended center-based care. In this area, it would seem that "catch-up" fostered by schools for disadvantaged students is not working as it should for HS participants in this subject, despite gains in working memory and cognitive flexibility that (slightly) exceed those of the more advantaged children. Moreover, the HS participants' kindergarten growth rates in math are slower (at 2.32 points) than those of children who received either informal care from relatives and non-relatives or parental care, and these differences are statistically different. In the next period, from the spring of kindergarten through the spring of second grade, the growth rates in math for all five groups are statistically comparable to one another (around 1.5 points per month).

Growth rates in reading demonstrate a different pattern, with HS participants' reading scores increasing at an average 2.74 points per month during kindergarten, significantly higher than either children who attended pre-k (2.46 points) or center-based care (2.65), and somewhat higher than another disadvantaged group, children who experienced only parental care (2.58 points). We don't know whether the HS students' steeper growth in reading in this first year of school occurs because of "priming" for this subject they received from experiences in HS, successful efforts by kindergarten teachers in support of their skills, or because for this group at least, growth in reading appears to be better supported by concurrent growth in EFs than growth in math is. In the second period, however, growth rates for all groups flattened to around 1.5 points per month, with no statistical differences among groups.

This finding of similar rates for growth rates for most children in the later period, however, does not mean that schools stop providing opportunities to help boost more disadvantaged children in the second period. After all, this later period includes two summers (between kindergarten and first grade and between first and second grades, or first grade only for DCCS scores); summer is a time of continued growth in academic achievement for more advantaged children, whose parents are likelier to arrange activities for them that stimulate cognitive growth. In contrast, disadvantaged children usually lack opportunities for learning during the summertime (Waldfogel, 2012). That growth rates for all groups are quite close for all groups in this period suggests that on average, schools may be doing the work of equalizing educational opportunity rather well; that they could be taking actions in first and second grades specifically intended to counter "summer learning loss," either through extended school time during summer or additional compensatory measures during the school years (Alexander, Entwistle, and Olson, 2001).

Models presenting evidence of relationships of math content level in kindergarten with the growth of outcomes of HS children as well as the other four ECE groups are presented in Tables 4 through 13. For each outcome in each table, The first model (1) estimates "fixed effects" for the four levels of math content as well as the growth curves on each outcome for "Period 1" (kindergarten) and "Period 2" (end of kindergarten through end of second grade). Estimation is then refined first in model (2) by interactions of each math content level with each of the periods, and then adjusted in model (3) for an extensive range of child, family, school, and teacher characteristics. These third models let us see whether rates of development and associations with math content levels hold steady for each group in consequence of additional lessons in each level of math content, net of important characteristics of children, families, teachers, and schools that typically affect development of the outcomes.

I discuss findings on each level of math content separately, underscoring significant associations with EF skills, math, and reading achievement, with particular focus on children who attended HS.

Level 1: Basic counting and shapes

Results in Table 4 for HS participants indicate that in preliminary modeling (1), the general pattern of results seen in earlier studies of math content in kindergarten is present for the associations of additional lessons on "Basic counting and shapes" with EF outcomes; significant negative "fixed" effects are apparent for both working memory (-.293, p<.05) and cognitive flexibility (-.028, p<.05). The negative association with working memory actually increases in size and significance (-.571, p<.01) in a model (2) that accounts for differential growth at two time periods associated with math content levels. In the fully adjusted model (3) it is smaller, and only marginally significant (-.339, p<.10). The negative association for this basic content level with DCCS scores does not persist in the subsequent, fully adjusted models (3).

While a small negative "fixed effect" of lessons in "Basic counting and shapes" (-.153, p<.05) in model (1) on reading outcomes in Table 5, it is actually positive in direction (and non-significant) in the final model. The fully-adjusted model suggests a very slight negative association of such content with reading scores of HS participants, only during the first and second grade period (-.008, p<.05).

Analysis in Table 6 suggests a small positive association of lessons on "Basic counting and shapes" with working memory skills of pre-k participants during the first and second grade period (.023, p<.05). Scores on cognitive flexibility appear to be largely unaffected by lessons on this type of math content, despite a small negative fixed effect in the model (1) without interactions or covariate adjustment (-.040, p<.05). A small negative association with pre-k students' growth rates in math achievement during first and second grades appears in the final, fully adjusted model on Table 7 (-.010, p<.05).

For children who attended center-based care (Table 8), lessons on "Basic counting and shapes" have a positive association with growth curves for the DCCS scores during the kindergarten period (.005, p<.05). In fully adjusted models, no significant associations result with working memory outcomes or growth rates. Center-based care participants appear to experience no effects of this very basic kindergarten math content in their growth rates in math or reading, although directions are generally negative. Unadjusted modeling (1) results in negative “fixed effects” for this group with both math and reading.

For the children who received informal care from relatives or non-relatives there appear to be no significant associations for lessons in “Basic counting and shapes” (Tables 10 and 11) with any of their outcomes; implications to be further explored in Discussion.

Children who received only parental care in the year preceding kindergarten appear to have slightly steeper growth curves in their Numbers Reversed scores during first and second grade in association with of additional lessons in “Basic Counting and shapes” (.019, $p<.05$), in the fully adjusted model. However, for this group there is a small but significant decrease in math learning during kindergarten in association with these lessons (-.023, $p<.05$, fully adjusted model); likewise, this lessons in this math content level are significantly associated with a similar decrease in reading scores (-.027, $p<.05$).

Level 2: Patterns and measurement

Lessons in “Pattern and measurement” appear to have no significant association with EF skills, math and reading outcomes or growth curves on any of these measures for HS participants (Tables 4 and 5).

For children who attended school-based pre-k, lessons in this content area have a significant negative association with math learning in kindergarten (-.028, $p<.05$); for children who attended another form of center-based care, this association is marginally significant and smaller (-.011, $p<.10$) (Tables 7 and 9).

Exceptionally, Table 12 presents a small “fixed effect” of lessons in “Patterns and measurement” in association with the DCCS scores of children who received only parental care in fully adjusted models (-.047, p<.05).

Level 3: Place value and currency

Fully adjusted models show a positive association (.016, p<.05) of additional lessons in this content area with math learning rates during kindergarten for HS participants, and a slight negative association (-.005, p<.05) with growth in the second time period. Interestingly, lessons on this content level also are associated with a slight positive increase in growth curves of reading scores during kindergarten (.017, p<.05) in fully adjusted modeling (Table 5). There is a very slight negative association (-.018, p<.05) with lessons in “Place value and currency” on the working memory skills of HS participants during first and second grades, with no significant effects on cognitive flexibility (Table 4). (Interestingly, both fixed effect estimates and estimates of associations of “Place value and currency” lessons with growth curves during kindergarten trend positive on both working memory and cognitive flexibility for this group.)

For children who attended pre-k, lessons on “Place value and currency” are associated with a slight increase in growth curves for math learning in kindergarten (.022, p<.05), with no significant effects on other outcomes. For children in the center-based care group, fully-adjusted models demonstrate that additional lessons in this content area are associated with a .013 (p<.01) increase in math growth rates during kindergarten. Interestingly, these children’s reading outcomes appear to be affected favorably as well, with a slight positive “fixed effect” (.066, p<.10), a small upward shift in slope during the kindergarten year (.012, p<.05), and a very small downward shift during the next period (.004, p<.05).

For children who received informal care from relatives and non-relatives (Table 11), lessons on “Place value and currency” have a positive association with math learning in kindergarten (.022, p<05), and with reading learning during the same period (.035, p<.001). For children who received only parental care (Table 13), lessons in this content area during kindergarten have a slight positive association on reading learning in kindergarten (.019, p<.05).

Addition and subtraction

For “Addition and subtraction,” the most advanced math content, there is a marginally significant negative “fixed effect” on the working memory scores of HS participants (-.339, p<.10). Additionally, there is a small decrease in monthly growth in this outcome during the first and second-grade time period for these children (-.018, p<.05). The fully-adjusted model (3) shows no effect for this content area on cognitive flexibility. However, additional lessons in “Addition and subtraction” are associated with both an increase the monthly growth rate for math scores of HS participants during kindergarten (.017, p<.01), and a slight decrease in their monthly growth rate in the subsequent period (-.005, p<.05).

Similarly, for children who attended pre-k, lessons in “Addition and subtraction” are associated with an increase in their monthly growth rates in math scores during kindergarten that is more substantive than that for HS participants (.020, p<.01), followed by slight decrease in the monthly growth rate in the subsequent period (-.005, p<.05).

On the math scores of children who received center-based care, lessons in this content area had a positive significant “fixed effect” (.061, p<.05), an increase in monthly growth rates (.013, p<.01), and a slight decrease in the monthly growth rate in the subsequent period (-.005, p<.001). On reading assessments for these children, the lessons had a positive significant “fixed effect” (.088, p<.01) and were associated with an increase in monthly growth rates (.012, p<.01) as well as a slight decrease in the monthly growth rate in the subsequent period (-.004, p<.01).

For children who received informal care from relatives or non-relatives, lessons on “Addition and Subtraction” have a slight negative association with math scores in the first- and second-grade period (-.008, p<.001). For children who received only parental care, lessons in this content area have a positive association with math growth rates during kindergarten (.014, p<.01), followed by a a marginally statistic association with decline in those growth rates in the subsequent period (-.003, p<.10).

Discussion

First, with other less advantaged groups of children, Head Start participants experience a period of high growth in working memory, cognitive flexibility, and reading during kindergarten, in which their growth rates outpace those of other children who attended center-based care. It is expected that disadvantaged children's growth rates in kindergarten are larger than those of more advantaged children, who have in many cases experienced high-quality ECE programs. However, Head Start participants' growth rates in math in this year are not statistically different from those of the more advantaged children. Second, advanced math content in kindergarten does have a positive relationship with math and reading achievement for Head Start participants, but they do not gain as much from this instructional approach, on average, as more advantaged children do. More basic math content, such as counting, has no association with the math achievement of Head Start children as a group, although it does have a negative association with growth in math for more advantaged groups of children. Lessons in advanced math content do not appear to provide significant benefit in EF development for any children. Associations for lessons in *more basic* math content are mixed; although such lessons have a marginally significant relationship with working memory outcomes of HS participants, they may provide slight gains to certain other groups of less advantaged children, specifically for working memory growth in first and second grades. Advanced math content instruction, specifically in "Place value and currency" appears to provide gains in reading growth in kindergarten for all groups of children, on average, except those who attended school-based pre-kindergarten programs. Finally, any gains in growth rates resulting from math content do not appear to persist through first and second grades. Details and implications relating to each question follow.

1) Once in school, do HS participants experience faster growth in EFs in comparison with *children who received other types of early care, and is their growth reflected in a parallel surge in academic achievement?*

HS participants' growth rates in kindergarten for working memory, cognitive flexibility, and reading achievement are all significantly higher than those of children who experienced other forms of center-based care (pre-k or other center-based) in the year preceding kindergarten. In most cases, the growth in these areas by children who attended HS is statistically no different than that of children who did not receive center-based care; this is positive news for HS participants, since these groups of children also experience a surge of growth as they enter school environments.

Growth rates in math for HS children, however, are statistically insignificant from those of children in the other center-based groups, despite their need for "catch-up" in this critical area given their low average initial scores in this area at the start of kindergarten. Despite their surge in EFs, when viewed in the framework of alternative care types HS participants do not appear to respond to the intervention of kindergarten with respect to math learning with the typical "bump up" at school entry for disadvantaged children. This makes the study of math-related interventions such as math content level especially critical.

2) *Does exposure to more advanced math content in kindergarten appear to support more math learning among HS participants and other groups in the kindergarten year?*

The growth rates of math outcomes for HS participants during kindergarten have small positive associations with additional lessons in both advanced content areas: "Place and currency" (.016, $p<.05$) and "Addition and subtraction" (.017, $p<.01$). Interestingly, children who attend public pre-k (and entered kindergarten with significantly higher math scores at baseline) appear to benefit more strongly from each additional lesson in both of these content areas in terms of their kindergarten growth rates: “Place and currency” (.022, p<.05) and “Addition and subtraction” (.020, p<.01).

Children who attended center-based care care (and score highest on math assessments of all groups at school entry) seem to receive smaller boosts to kindergarten growth rates from more advanced content lessons: “Place and currency” (.013, p<.01) and “Addition and subtraction” (.013, p<.01). However, they are the only group for which there is a significant positive “fixed effect” for lessons in “Addition and subtraction” (.061, p<.01).

For children who received informal care from relatives and non-relatives, growth curves in math learning during kindergarten are positively associated with lessons in “Place value and currency” (.022, p<.05). For children who received only parental care, math achievement in kindergarten is positively associated with lessons in “Addition and subtraction” (.014, p<.01). That these group form a somewhat distinct types of learners that seem to benefit from only one type of advanced math instruction is worth noting.

It is important to note that once kindergarten growth rates for kindergarten are adjusted for math content, those for HS participants fall to the lowest levels of any group (1.31, p<.001), and yet the significant associations for growth rates with advanced math content types do not provide them with especially large compensatory boosts. These children, who needed more help in this area than other children, appear to have benefited somewhat less on average from advanced math content than did other groups.

3) Does exposure to more basic math content (such as counting) negatively affect math learning in kindergarten for HS participants and other groups?

In the fully-adjusted model for HS participants’ kindergarten growth rates in math, there appear to be no negative associations for additional time on more basic math content, specifically for lessons in “Basic counting and shapes” or “Patterns and measurement.” In preliminary unadjusted models, “fixed effect” coefficients for both types of math content were negative and not more than marginally significant, with the coefficient for “Basic counting and shapes” becoming positive (and still non-significant) in the fully-adjusted model.

Similar models of growth curves in math for pre-k participants demonstrate a small negative association for lessons in “Patterns and measurement” (-.028, $p<.05$) during kindergarten. For children who attended center-based care, there is a smaller negative association for the same lessons that is marginally significant (-.011, $p<.10$). In the preliminary models for these groups, a significant negative association for lessons in “Basic counting and shapes” does appear as a “fixed effect,” but in each case it is fully accounted for by characteristics of children, families, schools, and teachers.

For mathematics achievement of children who received informal care from relatives and non-relatives, there are no significant negative associations with more basic math content in the fully adjusted models, although in uncontrolled models, coefficients for “Basic counting and shapes” are consistently negative.

In the fully-adjusted model, mathematics growth for children who received parental care has a negative association with lessons on “Basic counting and shapes” (-.023, $p<.05$).

In summary, kindergarten mathematics achievement for children who attended pre-k or center-based care or who received only parental care has a negative association with lessons in basic or remedial math content during that year. The lack of a similar finding for HS participants and children who received informal care may actually suggest within those groups some children are actually helped in their achievement by increased exposure to this type of content, while others’ outcomes may be negatively affected. This would be consistent with a sub-analysis in

Engel, Claessens, and Finch (2013) in which basic math content was helpful the math achievement to a subset of children with very low initial proficiency in math, in spite of being associated with lower achievement for most children in the study.

4) Does exposure to more basic or higher math content appear to EF outcomes, in particular working memory?

For HS participants, there is a negative, marginally significant "fixed effect" of lessons in "Basic counting and shapes" on working memory (-.339, p<.10). There are also *positive* associations for more basic math content and working memory, involving growth rates during first and second grade for specific groups. For example, for children who receive parental care in the year preceding kindergarten, there is a positive association with working memory growth rates during first and second grades for kindergarten lessons on "Basic counting and shapes" (.014, p<.05). Similarly, for children who attend pre-k, there is a positive association for lessons on "Basic counting and shapes" with their working memory growth rates in first and second grades (.023, p<.05).

Models also demonstrate both positive and negative associations for lessons in more advanced content with working memory growth rates. For Head Start participants, there is a negative coefficient for lessons on "Place Value and Currency" (-.018, p<.05) and working memory growth rates during first and second grades. For children who attend pre-k, there is a negative, marginally significant association for more advanced content, specifically lessons in "Place value and currency" with working memory growth curves in first and second grades (-.014, p<.10). For children who received only parental care, there is a positive association (.014, p<01) for lessons in "Addition and Subtraction" and working memory growth rates in kindergarten, followed by a negative, marginally significant association (-.003, p<.10) for the same type of lessons and working memory growth rates in first and second grades.

5) *Does exposure to higher math content positively affect reading growth achievement in kindergarten?*

Higher math content has positive associations with early reading achievement, common to almost all groups. The growth rates of HS participants during kindergarten have a positive association with additional lessons on “Place value and currency” (.016, $p<05$). For children who received center-based care, there are positive “fixed effects” coefficients for *both* advanced math content levels on the reading achievement of (.066, $p<.10$ for “Place value and currency”; .088, $p<.01$ for “Addition and subtraction”). Additionally, reading growth curves during kindergarten for these children have a slight positive association with lessons on “Place value and currency” (.012, $p<.05$).

Reading growth curves in kindergarten for children who receive informal care from relatives and non-relatives also have a positive association with lessons in “Place value and currency” (.035, $p<.001$). Similarly, growth rates in reading during the kindergarten year for children who received only parental care have a positive association with lessons on “Place value and currency” (.019, $p<.05$); they also have a negative association with lessons on “Basic counting and shapes” (-.027, $p<.05$).

It is not clear why for several groups of children positive associations for reading achievement in kindergarten emerge here in relationship to lessons on “Place and currency”; it may be that such lessons, which may involve word problems and stimulate consideration of language-related aspects of numerical problem-solving, are helpful to children’s early reading.

6) Do positive or negative “effects” of mathematics content on any outcomes persist, for any group of children as defined by early care type, through first and second grades?

Significant coefficients for interactions of math content and Period 2 (from the spring of kindergarten through the spring of second grade) are almost all negative, suggesting that the positive associations seen during Period 1 for several math content levels in the kindergarten year do not persist. Content levels with significant associations with kindergarten growth rates, to be clear, do not continue to have such associations with growth rates for first and second grades. Most often, positive associations for kindergarten are followed by negative ones in the second period. The negative associations for this period are almost all extremely small, suggesting that they merely signal the typical subsidence after a more significant change, a "regression to the mean" often seen after interventions of various kinds.

However, it is important to consider whether that the positive "effects" of advanced math content for HS children during kindergarten are significantly diminished by subsequent regression; specifically, the positive associations for the math achievement of HS children during kindergarten with additional lessons in "Place value and currency" (.016, $p<.05$) and "Addition and subtraction" (.017, $p<.01$) are each followed by significant negative associations of with math achievement first and second grade (-.005, $p<.05$ for "Place value and currency and -.005, $p<.01$ for "Addition and subtraction"). These Period 2 coefficients, while small, are monthly rates that apply for roughly twice the duration than those for the kindergarten period, so that they represent significant loss in average math achievement for each additional lesson in these areas that took place in kindergarten. We do not know what factors actually account for this decrease in math achievement in first and second grades associated with advanced math content, only that the degree of regression in this instance is greater, relative to the kindergarten boost, than in some others.

Another notable exception is a *positive* association of kindergarten lessons in "Basic counting and shapes" with working memory growth curves for first and second grades (.019, $p<.05$) in children of parental care, a particularly disadvantaged group on average. This association does not follow any positive association for this type of lesson with working memory growth in either "fixed effects" or with growth curves for the kindergarten period. It suggests a kind of "sleeper effect" or delayed boost in EF in consequence of early math support provided in kindergarten, a small but welcome benefit for children of a generally disadvantaged group.

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In summary, it is clear that for kindergarten mathematics content to be truly aligned with the needs of all students, it may be important to consider some of the mixed findings here on associations that differ by early care groups, reflecting varying results by level of disadvantage. Almost all groups appear to benefit in their math and reading growth rates during kindergarten from instruction featuring more advanced math content, but Head Start participants received smaller gains than some other children. For most children in the sample, exposure to more basic math content was associated with decreases in math growth rates, but for two groups, Head Start participants and those who received informal care from relatives and non-relatives, there was no association. I speculate that this lack of association suggests that within those groups, there may have been children whose developing math skills benefited from the more basic content as well as those for whom we would see the more common negative associations, were we to analyze them separately.

In terms of placing this research in context and thinking about future directions, it would be helpful to better understand the relative paucity of significant associations, for the most part, for math content with EF development, particularly with respect to the working memory of HS participants. That this group of particularly disadvantaged children begins kindergarten with especially depressed working memory skills (more than 60% are initially unable to score above a "0" on the Numbers Reversed task), and then experiences a relatively high rate of growth during kindergarten in this EF is promising; nonetheless, their kindergarten growth in math is not characterized by similar growth, in contrast to other disadvantaged children. It is as though on average, positive shifts in working memory for HS participants (and presumably for other highly disadvantaged children) do not occur "in time" to spur significant growth in their math skills – and as seen here, advanced math content in kindergarten is not generally a sufficient remedy for this problem. Since the optimal acquisition of early abilities in math typically follows a "learning trajectories" model (Clements, Sarama, Spitler, Lange, and Wolfe, 2011), a lack of sufficient early intervention at critical stages leads to on-going deficits in math skills, in a cascading effect that is likely to threaten long-term educational prospects. Indications are strong that serious early deficits in working memory are very difficult for children to recover from in terms of achievement (Morgan, Li, Farkas, Cook, Pun, Hillemeier, 2017*)*.

This calls to mind questions of how and whether ECE environments adequately prepare children to learn in school, and what can be adjusted across both ECE and school settings in order to minimize disparities in achievement. Research into early education curricula suggests that a "skills-based" curriculum in the preschool years is effective in boosting children's early academic abilities (Nguyen, 2017), but most Head Start programs follow an exclusively "whole child" curriculum in place of a format providing more pre-academic skills (Jenkins and Duncan, 2017). Interventions involving specialized curricula based in HS classrooms frequently show significant positive gains in EFs, social-emotional, and academic outcomes (Zhai, Raver, and Jones, 2012; Sasser, Bierman, Heinrichs, and Nix, 2017). However, as Head Start and the potential for "universal ECE" are being re-imagined (Chaudry and Waldfogel, 2016), it may be that the role of Head Start evolves into a fully available early services model (based on Early Head Start) targeting especially disadvantaged children at very early stages of development in the hope that their needs will be less severe by the time they reach the year preceding kindergarten. (Nonetheless, a universal plan for sufficiently addressing the cognitive needs of especially disadvantaged four-year-olds might also be helpful.)

For children once at school, findings here also suggest the usefulness of early screening and assessments for remedial, potentially small-group or individualized help in math at school entry. High-quality early math education in elementary school features certain “trajectory-based” processes that engender young children’s attention, EF skills, and early math abilities (Clements, Sarama, Germeroth, 2016), processes that the ECLS-K data may not capture. Also, programs featuring such processes – “high-quality” interventions in schools – are generally expensive, and thus not always scalable solutions. This problem is why studies on measures of “math content” could be important in on-going research, despite limitations.

Limitations

The most salient limitations to this analysis are directly related to the positive usefulness of “math content level” as a broad-based, inexpensive intervention. Some of these limitations, however, might be addressed. First, the modelling of the measures is somewhat imprecise, which could lead to unhelpful implementation of the research in classrooms. Although a control is included in all models for the total number of minutes each month for math instruction, the individual math content level variables are not measured in proportion with each other or with the total amount of math instruction children receive. These drawbacks could be at least partly remedied by the creation of a small number of patterns or profiles of math content instruction, along the lines of “activity settings” derived by Ansari and Purcell (2017) in analysis of the effects of direction instruction and child-directed learning. A study could operationalize how much of each child's day is spent on math instruction, how much time on various content levels, and other features of instruction could be more informative still on what patterns or profiles help or hinder children's growth in math and other outcomes.

Additionally, there are no benchmarks employed in the existing literature (or here), so that we don't get a sense of whether a particular number of lessons on a topic is associated with a gain or a deficit in learning curves. There is no sense of how many is sufficient, or how many might be "too many." Even the conclusions drawn from analysis here could be misleading, as a result; some children may have simply required more lessons of a particular kind in order for us to see a significant association with a particular outcome. However, it is unlikely that each additional lesson has the same additive effect on children's growth, and something might be gained by investigating statistical moments of these measures of lessons, or investigating benchmarks around particular findings.

Moreover, Engel, Claessens, and Finch (2013) note that the measures of time spent on different content levels did not account for the *quality* of instruction. There is much we do not know about how lessons were implemented, and we yet know that there are many aspects of instruction that can be particularly important for kindergarteners who are at-risk learners; as an example for such learners, individual student practice opportunities significantly predict greater effectiveness for one curriculum's effectiveness (Doabler, et al., 2018). A review of the ECLS-K data file from teacher surveys, however, might help to build more information on these factors into models.

Finally, whether or not effects of more time on various levels of math content persist beyond kindergarten may be affected by factors unaccounted for here in subsequent years, such as the use of routine practice and drill in math classes, which have been demonstrated to provide significant support in the math achievement of *first grade* students with math difficulties (defined as the bottom 15% of the ECLS-K 1998 cohort, as measured by their math competency in kindergarten, in Morgan, Farkas, and Maczuga, 2015). As we have seen in the Head Start literature, it is difficult to assess the persistence of gains, particularly for at-risk or disadvantaged learners, in the absence of context about subsequent learning environments. Potentially, a multi-year longitudinal inquiry into math content level over multiple waves, with growth rates for disparate groups of children could be more illuminating.

Finally, in analysis of the non-persistence of effects of an early mathematics intervention in order to determine whether benefits were lost through "constraining content" or because of pre-existing differences in students' backgrounds, researchers matched treated and control children on both baseline characteristics and their post-treatment level of achievement to establish that 72% of the fadeout effect stemmed from pre-existing characteristics (Bailey, Nguyen, Jenkins, Domina, Clements, and Sarama, 2016). While accounting for convergence was not my goal in this paper, an approach like this could be an important and interesting approach to understanding why efforts do not always have the wished-for results.

Tables

Table 2. 1: Descriptive Statistics by Head Start and Other Care Arrangements[8]

Variable	Head Start (n≈2,000)	Pre-K (n≈1,450)	Center-Based Care (n≈ 5,550)	Relative/ Non-Rel. Care (n≈1,350)	Parental Care (n≈ 2,590)
Child characteristics					
Gender					
Female	.472	.471	.494***	.526***	.495***
Male	.528	.529	.506**	.474***	.505*
Race/ethnicity					
White (non-Hispanic)	.314	.516***	.636***	.434***	.439***
Black (non-Hispanic)	.249	.105***	.080***	.153***	.122***
Hispanic	.323	.275**	.132***	.297	.319
Asian (non-Hispanic)	.053	.041+	.089***	.053	.057
Other (non-Hispanic)	.061	.063	.062+	.063	.067
Birthweight					
Normal birthweight	.890	.913+	.927***	.922*	.905
Low birthweight (< 2500 g)	.111	.087+	.073***	.078*	.095*
Child has diagnosed disability (parent report)	.202	.283***	.180*	.169+	.173*
Maternal characteristics					
Age at child's birth (years)	21.4	23.7	26.5	22.3	22.6
Education					
Less than high school	.195	.129***	.036***	.149**	.233*
High school graduate	.309	.233***	.129***	.279	.270*
Some college or technical	.372	.347	.308***	.394	.294***
College graduate	.124	.290***	.527***	.177***	.203***
Employment status					
Full-time	.406	.418	.492***	.610***	.203***
Part-time	.200	.198	.229**	.204	.180
Not working	.393	.383	.278***	.121***	.614***
Mother's health = poor (self-rated)	.160	.089***	.055***	.118*	.124*
Family characteristics					
Single parent household	.341	.187***	.144***	.325	.168***
Number of siblings	2.58	2.57	2.32	2.49	2.79
Poverty status					
Above 200% of poverty level	.254	.475***	.737***	.412***	.340***
Near poverty level	.276	.274	.154***	.287	.277
Below poverty level	.469	.252***	.109***	.300***	.383***
Benefit receipt					
WIC receipt (current)	.805	.557***	.274***	.621***	.598***
Welfare receipt (# months in past year)	.140	.067***	.036***	.093**	.112**
Food stamps receipt (# months in past year)	.540	.321***	.139***	.355***	.432***

[8] Group means weighted by survey sample and jackknife weights. Subsample sizes are rounded, in accordance with NCES guidelines, to the nearest 50 students. Subsamples rounded per NCES guidelines to nearest 50 students.

*** p<.001 ** p<.01 * p<.05 + p<.10

Table 2. 1: Descriptive Statistics by Head Start and Other Care Arrangements[8]					
Variable	Head Start (n≈2,000)	Pre-K (n≈1,450)	Center-Based Care (n≈ 5,550)	Relative/ Non-Rel. Care (n≈1,350)	Parental Care (n≈ 2,590)
Parent immigration status					
Only U.S. born parents	.592	.731***	.810***	.715***	.625
At least one born outside U.S.	.358	.283***	.223***	.302***	.385
Primary language in household					
English	.767	.844***	.925***	.829***	.741+
Non-English	.227	.160***	.087***	.169***	.250+
Child assessed in Spanish in Wave 1	.015	.029+	.002***	.026	.048***
Family lives in urban area	.783	.678***	.801*	.749**	.768*
Region of residence					
Northeast	.143	.131**	.189**	.112**	.122
Midwest	.212	.245	.255*	.234	.152***
South	.386	.463***	.326**	.383	.429*
West	.260	.161***	.228**	.270	.296**
School characteristics and experiences					
Full-day kindergarten	.884	.879	.780***	.831***	.808***
Public school	.954	.963***	.762***	.933***	.914***
School location in in urban area	.321	.213***	.180***	.259***	.256***
School enrolment	517	528***	503***	546***	551***
Percentage of ELL students	17.8	13.7***	10.5***	16.8***	17.6
Percentage receiving free/reduced price lunch	66.4	56.8***	33.0***	59.0***	56.4***
Teacher characteristics					
Years experience	14.2	13.6***	15.3***	14.5*	14.0*
Teacher qualifications					
Less than a bachelor’s degree	.003	.003	.010***	.004*	.005**
Bachelor’s degree	.525	.554***	.558***	.529*	.565***
Master’s or advanced degree	.472	.442***	.430***	.467+	.428***
Mathematics instruction in kindergarten					
Time on math in class (minutes/month)	376	366***	327***	361***	359***
Mathematics content level					
Basic counting and shapes	11.7	11.4***	10.8***	11.6+	11.8+
Patterns and measurement	7.78	8.01***	7.44***	7.86+	7.78
Place value and currency	10.3	10.4	10.5***	10.5**	10.5*
Addition and subtraction	9.37	9.39	9.18***	9.33	9.65***
Outcomes					
Continuous EF Measures					
Numbers Reversed (fall kindergarten)	425	434***	442***	428***	428***
Numbers Reversed (spring kindergarten)	442	449***	457***	446***	447***
Numbers Reversed (fall 1st grade)	453	455***	465***	455***	454***
Numbers Reversed (spring 1st grade)	470	472***	478***	471***	472***
Numbers Reversed (fall 2nd grade)	470	473***	478***	472***	472***
Numbers Reversed (spring 2nd grade)	477	479***	485***	479***	478***
DCCS “W” score (fall kindergarten)	13.8	14.3***	14.8***	14.0***	13.8

Table 2. 1: Descriptive Statistics by Head Start and Other Care Arrangements[8]

Variable	Head Start (n≈2,000)	Pre-K (n≈1,450)	Center-Based Care (n≈ 5,550)	Relative/ Non-Rel. Care (n≈1,350)	Parental Care (n≈ 2,590)
DCCS "W" score (spring kindergarten)	14.9	15.1***	15.6***	15.1***	14.9
DCCS "W" score (fall 1st grade)	15.5	15.8***	16.0***	15.8***	15.6
DCCS "W" score (spring 1st grade)	15.7	16.1***	16.4***	16.0***	15.9***
Cognitive IRT Scores					
Reading (fall kindergarten)	43.9	47.2***	50.4***	43.9	44.2**
Reading (spring kindergarten)	57.8	61.2***	65.1***	59.1***	59.0***
Reading (fall 1st grade)	64.3	67.8***	73.3***	66.9***	66.3***
Reading (spring 1st grade)	79.8	83.8***	88.8***	81.7***	81.4***
Reading (fall 2nd grade)	85.2	88.3***	93.0***	86.6***	86.2***
Reading (spring 2nd grade)	92.8	95.5***	100.0***	94.5***	93.9***
Math (fall kindergarten)	28.0	31.8***	35.7***	28.8***	28.7***
Math (spring kindergarten)	41.4	44.8***	48.9***	43.1***	42.8***
Math (fall 1st grade)	49.0	52.0***	58.0***	51.9***	51.1***
Math (spring 1st grade)	61.9	66.7***	71.4***	64.5***	63.7***
Math (fall 2nd grade)	67.1	70.4***	76.0***	69.4***	69.1***
Math (spring 2nd grade)	76.7	80.5***	84.9***	79.1***	78.6***

Table 2. 2: Growth Rates in Numbers Reversed and DCCS by ECE type, from fall of kindergarten through spring of second grade

	Numbers Reversed					DCCS				
	Head Start (n≈2,000)	Pre-K (n≈1,450)	Center-Based Care (n≈5,500)	Relative/ Non-Relative Care (n≈1,350)	Parental Care (n≈2,590)	Head Start (n≈2,000)	Pre-K (n≈1,450)	Center-Based Care (n≈5,500)	Relative/ Non-Relative Care (n≈1,350)	Parental Care (n≈2,590)
Initial level (fall K)	425	434***	442***	428	428	13.8	14.3	14.8***	14.0	13.8
Monthly growth: fall to spring kindergarten	3.08	2.65***	2.87*	3.19	3.20	.184	.156**	.151**	.189	.190
Monthly growth: spring kindergarten through spring 2nd grade (spring 1st grade for DCCS)	1.39	1.29	1.18**	1.34	1.34	.068	.076	.070	.075	.082+

Subsamples rounded per NCES guidelines to nearest 50 students.
Comparisons with Head Start participants: *** p<.001 ** p<.01 * p<.05 + p<.10
Monthly growth rates in points-gained-per-month. Adjusted for month of child's assessment in fall of kindergarten.

Table 2. 3: Monthly Growth Rates in Math and Reading by ECE type, from fall of kindergarten through spring of second grade

	Math					Reading				
	Head Start (n≈2,000)	Pre-K (n≈1,450)	Center-Based Care (n≈5,500)	Relative/ Non-Relative Care (n≈1,350)	Parental Care (n≈2,590)	Head Start (n≈2,000)	Pre-K (n≈1,450)	Center-Based Care (n≈5,500)	Relative/ Non-Relative Care (n≈1,350)	Parental Care (n≈2,590)
Initial level (fall K)	28.1	31.9***	35.8***	29.1*	28.8*	44.0	47.3***	50.6***	44.1	44.4+
Monthly growth: fall to spring kindergarten	2.32	2.26	2.41	2.52*	2.45+	2.74	2.46**	2.65*	2.69	2.58*
Monthly growth: spring kindergarten through spring 2nd grade	1.49	1.50	1.49	1.49	1.50	1.52	1.48	1.48	1.50	1.50

Subsamples rounded per NCES guidelines to nearest 50 students.
Comparisons with Head Start participants: *** p<.001 ** p<.01 * p<.05 + p<.10
Monthly growth rates in points-gained-per-month. Adjusted for month of child's assessment in fall of kindergarten.

Table 2. 4: Monthly growth rates in executive functions for Head Start participants: effects for time on math content levels

	Numbers Reversed			DCCS		
	Lessons per month on math content levels (1)	With interactions: math content levels with time periods (2)	Fully adjusted: child, family, school and teacher characteristics (3)	Lessons per month on math content levels (1)	With interactions: math content levels with time periods (2)	Fully adjusted: child, family, school and teacher characteristics (3)
Lessons/month on math content:						
Basic counting and shapes	-.293*	-.571**	-.339+	-.028*	-.003	.017
Patterns and measurement	-.191	-.138	-.049	.000	-.022	-.013
Place value and currency	.046	.222	.141	.021*	.018	.008
Addition and subtraction	.160	.287	.092	.000	-.001	-.006
Period 1: fall to spring kindergarten						
Intercept	3.11***	2.66***	2.00***	.190	.197***	.145**
Period 1 X Basic counting and shapes		.037	.035		-.004	-.004
Period 1 X Patterns and measurement		-.035	-.036		.002	.001
Period 1 X Place value and currency		.015	.016		.003	.004
Period 1 X Addition and subtraction		.014	.016		-.001	-.001
Period 2: spring kindergarten through spring 2nd grade (thru spring 1st grade for DCCS)						
Intercept	1.43***	1.48***	.828***	.070***	.074**	.027
Period 2 X Basic counting and shapes		.008	.009		-.001	-.001
Period 2 X Patterns and measurement		.008	.007		-.001	-.001
Period 2 X Place value and currency		-.018*	-.018*		-.002+	-.002
Period 2 X Addition and subtraction		-.002	-.003		-.001	.001

Subsamples rounded per NCES guidelines to nearest 50 students.
*** p<.001 ** p<.01 * p<.05 + p<.10
Monthly growth rates in points-gained-per-month. All models adjusted for month of child's assessment in fall of kindergarten.

Table 2. 5: Monthly growth rates in math and reading for Head Start participants: effects for time on math content levels

	Math IRT			Reading IRT		
	Lessons per month on math content levels (1)	With interactions: math content levels with time periods (2)	Fully adjusted: child, family, school and teacher characteristics (3)	Lessons per month on math content levels (1)	With interactions: math content levels with time periods (2)	Fully adjusted: child, family, school and teacher characteristics (3)
Lessons/month on math content:						
Basic counting and shapes	-.0007	-.073	.089	-.153*	-.110	.026
Patterns and measurement	-.082+	-.127+	-.090	-.064	-.078	-.051
Place value and currency	.127*	.113*	.061	.094+	.105*	.067
Addition and subtraction	-.060	.046	.021	.038	.043	.019
Period 1: fall to spring kindergarten						
Intercept	2.31***	2.073***	1.31***	2.36***	2.19***	1.68***
Period 1 X Basic counting and shapes		-.014	-.014		.001	.000
Period 1 X Patterns and measurement		.008	.008		-.006	-.006
Period 1 X Place value and currency		.016*	.016*		.017*	.017*
Period 1 X Addition and subtraction		.017**	.017**		.003	.003
Period 2: spring kindergarten through spring 2nd grade (thru spring 1st grade for DCCS)						
Intercept	1.48***	1.607***	.839***	1.52***	1.65***	1.34***
Period 2 X Basic counting and shapes		-.002	-.002		-.010*	-.009*
Period 2 X Patterns and measurement		-.001	.001		.004	.003
Period 2 X Place value and currency		-.006*	-.005*		-.003	-.003
Period 2 X Addition and subtraction		-.005*	-.005*		-.001	-.001

Subsamples rounded per NCES guidelines to nearest 50 students.
*** p<.001 ** p<.01 * p<.05 + p<.10
Monthly growth rates in points-gained-per-month. All models adjusted for month of child's assessment in fall of kindergarten.

Table 2. 6: Monthly growth rates in executive functions for pre-k participants: effects for time on math content levels

	Numbers Reversed			DCCS		
	Lessons per month on math content levels (1)	With interactions: math content levels with time periods (2)	Fully adjusted: child, family, school and teacher characteristics (3)	Lessons per month on math content levels (1)	With interactions: math content levels with time periods (2)	Fully adjusted: child, family, school and teacher characteristics (3)
Lessons/month on math content:						
Basic counting and shapes	-222	-.256	.044	-.040*	-.050+	-.027
Patterns and measurement	-.280	-.361	-.334	-.016	.018	.020
Place value and currency	.179	.265	.086	.030*	.032+	.014
Addition and subtraction	.032	-.256	-.222	-.001	-.023	-.019
Period 1: fall to spring kindergarten						
Intercept	2.61***	2.62***	2.34***	.138***	.160**	.144**
Period 1 X Basic counting and shapes		-.059	-.058		.001	.001
Period 1 X Patterns and measurement		.015	.014		-.005	-.005
Period 1 X Place value and currency		.022	.024		-.003	-.003
Period 1 X Addition and subtraction		.033	.033		.004	.004
Period 2: spring kindergarten through spring 2nd grade (thru spring 1st grade for DCCS)						
Intercept	1.34***	1.16***	.887***	.079***	.058*	.040
Period 2 X Basic counting and shapes		.022*	.023*		.001	.001
Period 2 X Patterns and measurement		-.001	.001		-.002	.002
Period 2 X Place value and currency		-.013	-.014+		.002	.002
Period 2 X Addition and subtraction		.007	.007		.001	.001

Subsamples rounded per NCES guidelines to nearest 50 students.
*** p<.001 ** p<.01 * p<.05 + p<.10
Monthly growth rates in points-gained-per-month. All models adjusted for month of child's assessment in fall of kindergarten.

Table 2. 7: Monthly growth rates in math and reading for pre-k participants: effects for time on math content levels

	Math IRT			Reading IRT		
	Lessons per month on math content levels (1)	With interactions: math content levels with time periods (2)	Fully adjusted: child, family, school and teacher characteristics (3)	Lessons per month on math content levels (1)	With interactions: math content levels with time periods (2)	Fully adjusted: child, family, school and teacher characteristics (3)
Lessons/month on math content:						
Basic counting and shapes	-.198*	-.211*	-.014	-.184*	-.129	.019
Patterns and measurement	-.047	-.013	.048	-.012	-.015	.004
Place value and currency	.162*	.140*	.018	.160*	.160*	.068
Addition and subtraction	-.011	-.033	-.053	-.013	.011	.010
Period 1: fall to spring kindergarten						
Intercept	2.21***	1.87***	1.40***	2.4***	2.21***	2.03***
Period 1 X Basic counting and shapes		.015	.013		.006	.005
Period 1 X Patterns and measurement		-.028*	-.028*		.008	.007
Period 1 X Place value and currency		.021*	.022*		.009	.010
Period 1 X Addition and subtraction		.020**	.020**		-.001	-.003
Period 2: spring kindergarten through spring 2nd grade (thru spring 1st grade for DCCS)						
Intercept	1.51***	1.64***	1.16***	1.48***	1.59***	1.38***
Period 2 X Basic counting and shapes		-.010*	-.010*		-.007	-.007
Period 2 X Patterns and measurement		.006	.006		-.001	-.001
Period 2 X Place value and currency		-.002	.002		-.001	-.001
Period 2 X Addition and subtraction		-.005*	-.005*		-.001	-.002

Subsamples rounded per NCES guidelines to nearest 50 students.
*** $p<.001$ ** $p<.01$ * $p<.05$ + $p<.10$
Monthly growth rates in points-gained-per-month. All models adjusted for month of child's assessment in fall of kindergarten.

Table 2. 8: Monthly growth rates in executive functions for center-based care participants: effects for time on math content levels

	Numbers Reversed			DCCS		
	Lessons per month on math content levels (1)	With interactions: math content levels with time periods (2)	Fully adjusted: child, family, school and teacher characteristics (3)	Lessons per month on math content levels (1)	With interactions: math content levels with time periods (2)	Fully adjusted: child, family, school and teacher characteristics (3)
Lessons/month on math content:						
Basic counting and shapes	-.028	-.210	-.084	-.007	-.016	-.005
Patterns and measurement	-.013	-.046	-.007	-.007	-.006	-.002
Place value and currency	.076	.029	-.033	.126*	.021*	.015
Addition and subtraction	.008	.117	.105	-.003	-.008	-.010
Period 1: fall to spring kindergarten						
Intercept	2.86***	2.60***	1.05***	.150***	.132***	.091***
Period 1 X Basic counting and shapes		.007	.006		-.005*	-.005*
Period 1 X Patterns and measurement		.001	.001		-.003	-.002
Period 1 X Place value and currency		.016	.015		-.002	-.002
Period 1 X Addition and subtraction		.002	.003		.002+	.001
Period 2: spring kindergarten through spring 2nd grade (thru spring 1st grade for DCCS)						
Intercept	1.16***	1.14***	.566***	.066***	.075***	.038
Period 2 X Basic counting and shapes		.009	.010		-.002*	-.002
Period 2 X Patterns and measurement		.002	.002		.002_	.002
Period 2 X Place value and currency		-.002	-.002		.001	.001
Period 2 X Addition and subtraction		-.007	-.008		.001	.001

Subsamples rounded per NCES guidelines to nearest 50 students.
*** p<.001 ** p<.01 * p<.05 + p<.10
Monthly growth rates in points-gained-per-month. All models adjusted for month of child's assessment in fall of kindergarten.

Table 2. 9: Monthly growth rates in math and reading for center-based care participants: effects for time on math content levels

	Math IRT			Reading IRT		
	Lessons per month on math content levels (1)	With interactions: math content levels with time periods (2)	Fully adjusted: child, family, school and teacher characteristics (3)	Lessons per month on math content levels (1)	With interactions: math content levels with time periods (2)	Fully adjusted: child, family, school and teacher characteristics (3)
Lessons/month on math content:						
Basic counting and shapes	-.118*	-.126*	-.052	-.178**	-.153*	-.066
Patterns and measurement	.018	.038	.082	.077+	.043	.075
Place value and currency	.096*	.084*	.026	.067+	.102*	.066+
Addition and subtraction	.047	.071*	.061*	.037	.106**	.088**
Period 1: fall to spring kindergarten						
Intercept	2.39***	2.21***	1.54***	2.65***	2.61***	2.18***
Period 1 X Basic counting and shapes		-.001	-.001		-.011	-.011
Period 1 X Patterns and measurement		-.010	-.011+		.003	.003
Period 1 X Place value and currency		.013*	.013**		.011*	.012*
Period 1 X Addition and subtraction		.013**	.013**		.001	.002
Period 2: spring kindergarten through spring 2nd grade (thru spring 1st grade for DCCS)						
Intercept	1.50***	1.55***	.848***	1.49***	1.56***	1.11***
Period 2 X Basic counting and shapes		.001	.001		-.002	-.001
Period 2 X Patterns and measurement		-.001	-.001		.002	.002
Period 2 X Place value and currency		-.001	-.001		-.004*	-.004*
Period 2 X Addition and subtraction		-.005***	-.005***		-.005**	-.005**

Subsamples rounded per NCES guidelines to nearest 50 students.
*** p<.001 ** p<.01 * p<.05 + p<.10
Monthly growth rates in points-gained-per-month. All models adjusted for month of child's assessment in fall of kindergarten.

Table 2. 10: Monthly growth rates in executive functions for recipients of informal care from relatives/non-relatives: effects for time on math content levels

	Numbers Reversed			DCCS		
	Lessons per month on math content levels (1)	With interactions: math content levels with time periods (2)	Fully adjusted: child, family, school and teacher characteristics (3)	Lessons per month on math content levels (1)	With interactions: math content levels with time periods (2)	Fully adjusted: child, family, school and teacher characteristics (3)
Lessons/month on math content:						
Basic counting and shapes	-.385*	-.624*	-.373	-.029+	-.030	-.015
Patterns and measurement	-.071	-.030	-.030	-.005	-.035	-.029
Place value and currency	.387**	.343*	.223	.038**	.040+	.028
Addition and subtraction	-.185+	-.178	-.137	-.022*	-.017	-.014
Period 1: fall to spring kindergarten						
Intercept	3.22***	2.52***	1.93***	.183***	.172**	.133*
Period 1 X Basic counting and shapes		.039	.041		-.003	-.003
Period 1 X Patterns and measurement		-.017	-.016		.006	.006
Period 1 X Place value and currency		.029	.027		.001	.001
Period 1 X Addition and subtraction		.008	.009		-.001	-.001
Period 2: spring kindergarten through spring 2nd grade (thru spring 1st grade for DCCS)						
Intercept	1.37***	1.42***	.840***	.077***	.056*	.023
Period 2 X Basic counting and shapes		.003	.003		.003	.003
Period 2 X Patterns and measurement		.003	.003		-.000	-.001
Period 2 X Place value and currency		-.007	-.006		-.001	-.001
Period 2 X Addition and subtraction		-.003	-.003		.001	.001

Subsamples rounded per NCES guidelines to nearest 50 students.
*** p<.001 ** p<.01 * p<.05 + p<.10
Monthly growth rates in points-gained-per-month. All models adjusted for month of child's assessment in fall of kindergarten.

Table 2. 11: Monthly growth rates in math and reading for recipients of informal care from relatives/non-relatives: effects for time on math content levels

	Math IRT			Reading IRT		
	Lessons per month on math content levels (1)	With interactions: math content levels with time periods (2)	Fully adjusted: child, family, school and teacher characteristics (3)	Lessons per month on math content levels (1)	With interactions: math content levels with time periods (2)	Fully adjusted: child, family, school and teacher characteristics (3)
Lessons/month on math content:						
Basic counting and shapes	-.194*	-.184+	.009	-.220*	-.171+	-.013
Patterns and measurement	-.012	-.008	-.008	.065	.014	.012
Place value and currency	.103	.073	-.014	.101	.096	.023
Addition and subtraction	-.011	.001	.024	.038	.066	.080
Period 1: fall to spring kindergarten						
Intercept	2.51***	2.33***	1.64***	2.68***	2.50***	1.95***
Period 1 X Basic counting and shapes		-.014	-.156		-.012	-.012
Period 1 X Patterns and measurement		.004	.002		.009	.008
Period 1 X Place value and currency		.022*	.022*		.035***	.035***
Period 1 X Addition and subtraction		.011	.010		-.13	-.002
Period 2: spring kindergarten through spring 2nd grade (thru spring 1st grade for DCCS)						
Intercept	1.50***	1.55***	.855	1.51***	1.58***	1.03***
Period 2 X Basic counting and shapes		.001	.002		-.005	-.005
Period 2 X Patterns and measurement		-.004	-.004		.005	.005
Period 2 X Place value and currency		.004	.003		-.003	-.003
Period 2 X Addition and subtraction		-.008***	-.008***		-.002	-.002

Subsamples rounded per NCES guidelines to nearest 50 students.
*** p<.001 ** p<.01 * p<.05 + p<.10
Monthly growth rates in points-gained-per-month. All models adjusted for month of child's assessment in fall of kindergarten.

Table 2. 12: Monthly growth rates in executive functions for parental care recipients: effects for time on math content levels

	Numbers Reversed			DCCS		
	Lessons per month on math content levels (1)	With interactions: math content levels with time periods (2)	Fully adjusted: child, family, school and teacher characteristics (3)	Lessons per month on math content levels (1)	With interactions: math content levels with time periods (2)	Fully adjusted: child, family, school and teacher characteristics (3)
Lessons/month on math content:						
Basic counting and shapes	-.294+	-.529**	-.129	-.037*	-.050*	-.021
Patterns and measurement	-.084	.147	.072	-.004	-.050+	-.047*
Place value and currency	.160	.337*	.201	.027*	.031+	.020
Addition and subtraction	.036	-.060	.008	.006	.014	.018
Period 1: fall to spring kindergarten						
Intercept	3.27***	3.71***	3.23***	.189***	.160***	.117**
Period 1 X Basic counting and shapes		-.006	-.006		.001	.001
Period 1 X Patterns and measurement		-.019	-.019		.007	.007
Period 1 X Place value and currency		-.037	-.038		-.002	-.002
Period 1 X Addition and subtraction		.018	.017		-.002	-.002
Period 2: spring kindergarten through spring 2nd grade (thru spring 1st grade for DCCS)						
Intercept	1.33***	1.17***	.682***	.077***	.047*	-.002
Period 2 X Basic counting and shapes		.018*	.019*		.001	.001
Period 2 X Patterns and measurement		-.009	-.009		.001	.001
Period 2 X Place value and currency		.001	-.001		.001	.001
Period 2 X Addition and subtraction		.001	.001		.001	.001

Subsamples rounded per NCES guidelines to nearest 50 students.
*** p<.001 ** p<.01 * p<.05 + p<.10
Monthly growth rates in points-gained-per-month. All models adjusted for month of child’s assessment in fall of kindergarten.

Table 2. 13: Monthly growth rates in math and reading for parental care recipients: effects for time on math content levels

	Math IRT			Reading IRT		
	Lessons per month on math content levels (1)	With interactions: math content levels with time periods (2)	Fully adjusted: child, family, school and teacher characteristics (3)	Lessons per month on math content levels (1)	With interactions: math content levels with time periods (2)	Fully adjusted: child, family, school and teacher characteristics (3)
Lessons/month on math content:						
Basic counting and shapes	-.259**	-.247**	.015	-.185*	-.199*	.005
Patterns and measurement	.009	.017	-.034	-.036	.004	-.059
Place value and currency	.148**	.139*	.029	.144**	.142**	.058
Addition and subtraction	.032	.026	.058	.030	.015	.042
Period 1: fall to spring kindergarten						
Intercept	2.46***	2.56***	1.90***	2.59***	2.64***	2.24***
Period 1 X Basic counting and shapes		-.023*	-.023*		-.026*	-.027*
Period 1 X Patterns and measurement		-.008	-.008		.009	.008
Period 1 X Place value and currency		.009	.009		.019*	.019*
Period 1 X Addition and subtraction		.013**	.014**		-.001	-.001
Period 2: spring kindergarten through spring 2nd grade (thru spring 1st grade for DCCS)						
Intercept	1.50***	1.47***	.819***	1.50***	1.50***	1.11***
Period 2 X Basic counting and shapes		.005	.005		.004	.004
Period 2 X Patterns and measurement		-.002	-.002		-.006	-.006
Period 2 X Place value and currency		.002	.002		-.003	-.003
Period 2 X Addition and subtraction		-.003+	-.003+		.002	.002

Subsamples rounded per NCES guidelines to nearest 50 students.
*** p<.001 ** p<.01 * p<.05 + p<.10
Monthly growth rates in points-gained-per-month. All models adjusted for month of child's assessment in fall of kindergarten.

Appendix

Appendix 2A: Survey items (from teacher surveys) comprising numbers of lessons for math content levels.

Level 1: Basic shapes and counting	Level 2: Patterns and measurement	Level 3: Place value and currency	Level 4: “Addition and subtraction
Count out loud*	Use measuring instruments	Know value of coins and currency	Add single digit numbers
Handle geometric manipulatives*	Identify relative quantity	Know place value	Subtract single digit numbers
Use number line*	Order objects	Read two-digit numbers	
Name geometric shapes	Making/copying patterns	Recognize ordinal numbers	
	Sort objects into groups		

Coding math content levels followed procedures outlined in the online appendix to Engel, Claessens, Watts, and Farkas (2016). On most items, teachers were asked how frequently they taught the content and provided with these choices: 1) it should be taught at a higher level; 2) children should already know; 3) once a month or less 4) two or three times a month; 5) once or twice a week; 6) three or four times a week.
*Exceptionally, for items above marked with an asterisk, teachers were provided with slightly different choices: 1) never; 2) once a month or less; 3) two or three times a month; 4) once or twice a week; 5) three or four times a week; 6) daily.

Variables for each item were then coded (again following Engel, ibid.) as “1” if teachers responded that they taught an item once a month or less; “2.5” if two to three times; “6” if once or twice a week; “14” if three or four times a week; and “20” if every day. These variables were totalled in the generation of the four content level variables.

VIII. Paper 3: How does growth in executive functions, math, and reading in the early school years compare between Head Start participants with immigrant parents and participants with non-immigrant parents?

Introduction

This third investigation employs elements from the previous two papers as a framework in which to compare the development of EF skills, math, and reading achievement of the children of immigrant parents who attend Head Start (HS) with those of HS participants who are children of non-immigrant parents. Many of these children begin school with especially large deficits in cognitive outcomes, yet to my knowledge no study to date examines the trajectories of EF skills and related outcomes of reading and math in the critical transition years, from ECE into the early elementary grades, for HS participants with immigrant parents. Because of an especially high surge during the early 2000s in births to immigrant women living in the U.S. (Livingston and Cohn, 2012), 30.2% of children in the ECLS-K:2011 cohort have at least one immigrant parent. While a large proportion of children of immigrant parents (about 26%) in the full analytic sample were cared for exclusively by their parents in the year before kindergarten, many of their parents (roughly 17%) enrolled their children in HS programs. Since approximately 51.4% of this subgroup of HS participants live below the U.S. poverty level, with 61.9% of them in homes in which a non-English language is the primary language, it is clear that these children are challenged in particular ways that may affect both their outcomes and how interventions affect them. It is important to look more closely at what gains in EF skills, reading, and math the children of immigrant parents make after HS participation and, in particular, whether specific instructional practices, such as kindergarten exposure to math content, play a differential role in their development. I shall begin by examining question *#1: Without* *consideration of math content levels, do growth curves for the subgroups defined by parent nativity differ for working memory, cognitive flexibility, math or reading?*

In the first few years of school, many children of immigrant parents experience a surge of growth, “catching up” to children of non-immigrant parents in some cases across multiple outcomes (Reardon and Galindo, 2009; Coll and Marks, 2012), which suggests that the schools these children attend are generally somewhat effective in diminishing achievement gaps for these children. Many districts support and even mandate the provision of Dual Language Learning (DLL) and ELL (English Language Learning) programs to assist children of immigrant parents in this regard, but there is clearly more to be learned about the specific cognitive needs of this subgroup. In paper #2, evidence suggests that exposure to advanced math content in kindergarten is positively associated with the growth rates in math scores of HS participants, while exposure to more basic math content has no association with their math outcomes. Here, I shall examine whether there are differential effects for children of immigrant parents, with *Question #2: Do associations between exposure to either advanced or more basic math content and the growth rates of math for HS participants vary by children’s parent nativity?*

Additionally, paper #2 presented evidence suggesting that math lessons in “Place value and currency” have substantive positive associations with growth curves in reading for children across several groups, including HS participants. I have no hypothesis about whether this type of instruction is more or less helpful to the children of immigrant parents attending HS (or helpful to the same degree as it is to the group as a whole), but given the challenges around language abilities for many children of immigrant parents and the need to determine what instructional practices could benefit their literacy skills, I shall investigate question *#3): Does exposure to either more basic or advanced math content have different associations with the growth rates in* *reading for HS participants with immigrant parents?*

Additionally, in paper #2, it was seen that for Head Start participants there was a marginally significant negative "fixed effect" association between exposure to more basic math content and working memory outcomes (-.339, p<.10). Especially given the strongly predictive relationship of working memory to achievement (Duncan and Nguyen, 2017), this suggests that it is important to ask question *#4: Do associations between any level of math content and growth curves in EFs vary for HS participants with immigrant parents?*

Literature Review

Children of immigrant parents: Diversity in characteristics and factors for early achievement

U.S. Children of immigrant parents are a heterogeneous group in many respects; various aspects of families' lives strongly affect their children's outcomes in different directions. The results of an examination of early academic achievement for children of immigrant parents using the ECLS-K:2011 underscore the relevance of differentiating models by parents' country of origin in addition to other demographic controls (Sullivan, Houri, Sadeh, 2016). Analysis of math and reading scores at kindergarten entrance demonstrate highly significant gaps, with children of parents born in Mexico scoring, on average, almost seven points *below* white children of non-immigrant parents on reading and math scores, and children with parents born in East Asia scoring, on average, roughly six points *above* the same reference group on both math and reading scores. A similar "trimodal" framework of children's outcomes by parent's country of origin is seen elsewhere in literature describing achievement of children of immigrant parents (e.g., Han, Lee, and Waldfogel, 2012). Investigation of early learning practices in immigrant homes finds disparities by disparate cultures, such that on average, children's social-emotional functioning may be better supported in Latino households, while Asian mothers, in general, provide stronger learning practices for their children (Jung, Fuller, and Galindo, 2012). However, it is critical to note that in their full-cohort analysis, Sullivan, Houri, and Sadeh (2016) demonstrate that in fully-adjusted models controlling for child and family characteristics, the statistical significance of differences in reading and math by parent's country of origin fades completely. Factors that remain highly significant in fully-adjusted models include children's English proficiency at the start of kindergarten, the home language, parental education and income, and parents' marital status, along with the number of siblings in the family. In related work, Pong and Landale (2012) find that immigrant parents' pre-migration educational levels are more strongly associated with their children's achievement than any other single attribute.

The cognitive outcomes of many children of immigrant parents in the U.S. are below average at school entry (Sullivan, ibid.), although many exhibit positive learning trajectories, relative to their challenging beginnings, that can be both surprising and complex (Hernandez, Denton, Macartney and Blanchard, 2012). As a result, there is significant interest in their school-readiness and in determining what conditions form obstacles or advantages for them in comparison to children of non-immigrant parents. In an investigation of immigrants' children's cognitive abilities at kindergarten entry, Han, Lee, and Waldfogel (2012) traced factors explaining the variation in their reading and math outcomes. Expressive language skills and language background, including the primary language spoken in their homes and their parents' English proficiency level, were central in accounting for reading outcomes of the children of immigrant parents, while math outcomes were explained largely by immigrant families' socioeconomic status and language background. Interestingly, however, early care arrangements and parenting behaviors, which typically affect the school-readiness of children of non-immigrant parents, were not shown in this study to influence outcomes significantly for the children of immigrant parents, indicating potential differences in family processes and, perhaps, in these children's development as early learners.

Children of immigrant parents: Early language and the advantages of ECE and HS participation

Other studies suggest that early care programs of sufficient quality are vital for the educational prospects of the children of immigrant parents, particularly for children from disadvantaged backgrounds with low levels of English proficiency; equally essential is that these programs implement language supports and stimulation constructed with the specific needs of Dual Language Learners (DLLs) in mind (Castro, Martinez, and Páez, 2011). Notably, a longitudinal study of bilingual HS participants finds that for children's development during ECE, what critically predicts early reading achievement and literacy is *growth* in either language (English or their home language) fostered during the preschool period, rather than a particular score in either language at a particular point in time (Hammer, Lawrence, and Miccio, 2007). In contrast, other research (using the ECLS-K cohort data for children who entered kindergarten in 1998) suggests that the earlier in elementary school children become proficient in English, on average, the more quickly they are able to keep pace with similar English-speaking children in math and reading outcomes (Halle, Hair, Wandner, McNamara, and Chien, 2012).

With particular attention to disadvantaged subgroups, studies have examined the relative benefits of ECE investment for the children of immigrant parents; evidence suggests positive associations with reading outcomes for children of low-income immigrant parents who attend subsidized center-based care, in contrast to associations for children of non-immigrant parents (Johnson, Han, Ruhm, and Waldfogel, 2014). Such findings suggest that children of immigrant parents, particularly those from disadvantaged families, may benefit differentially from certain settings, or types of instruction; researchers have in fact investigated potential differential effects for the children of immigrant parents in a variety of contexts, including for HS participation. An early study of the role of preschool attendance in the early achievement of immigrants' children (Magnuson, Lahaie, and Waldfogel, 2006) finds that while in general preschool benefits the cognitive development of such children *as much* as it does that of children of non-immigrant parents, HS particularly boosts the English proficiency of the children of immigrant mothers with less than a high school education. In a study that employs ECLS-K:2011 data to focus more narrowly on the children of Hispanic immigrant parents, Padilla and Ryan (2018) present evidence that HS provides significant gains in their math, reading, and Approach to Learning (ATL) outcomes in comparison to home-based care by parents or relatives. Another investigation of school readiness and preschool for children of immigrant mothers, using other data, finds that children's HS attendance, when it exceeds twenty hours per week, improves children's reading scores, although not their math scores (Lee, Han, Waldfogel, and Brooks-Gunn, 2018). Bitler, Hoynes and Domina (2014) find persistent cognitive effects of Head Start participation for Spanish-speaking students through first grade; this subgroup finding is not at all trivial, since figures from 2007, two years before children in this study attended the program, indicate Dual Language Learners (DLLs) made up more than 30% of HS enrollment, with over 85% of these children speaking Spanish as their primary language (USDHHS-ACF, 2013).

Children of immigrant parents: Variation in trajectories of academic achievement and bilingualism

Notwithstanding the overriding importance of socioeconomic factors with respect to the outcomes of children of immigrant parents, early deficits tend to be quite difficult to overcome. Significant research on children's achievement trajectories during grade school has focused on variation by ethnic groups, and some of this research naturally has great relevance for many children of immigrant parents. In examining outcomes for Hispanic students as a whole (using the ECLS-K dataset for children entering kindergarten in 1998), Reardon and Galindo (2009) trace large gaps in math and reading outcomes at school entry with those of white children, with each gap measuring at least -.5 SD in size. Encouragingly, these gaps narrow in the first two years of school by about a third of their original size but then remain stable in subsequent years of this analysis (through fifth grade). Importantly, however, these researchers find subgroup differences so substantive that Hispanic children of immigrant parents who were born in Mexico or Central America have the lowest scores at school entry in both math (more than -1 SD on average) and reading (closer to -.7 or -.8 SD). Notably, these children exhibit greater and more persistent average gains than other Hispanic subgroups, with trajectories in math for "first" generation immigrant parents (children who immigrated themselves, usually with parents or other relatives) *continuing* in a positive direction through fifth grade.

Reardon and Galindo (2009) also explore a generally important aspect of immigrant achievement already touched on here: differences in trajectories arising from language used in the home and children's level of proficiency at school entry. They note the lower average levels, in their study, in the outcomes of children living in homes in which only Spanish is spoken, and a slight advantage in achievement for children living in bilingual homes (in which primarily English is spoken) *over* those of children in English-only homes. In a study of bilingualism's effects on the achievement of children *across* ethnic groups, Han (2012) categorizes students in four groups: English monolingual, mixed bilingual, non-English-dominant bilingual, and non-English monolingual children. The latter two groups, who speak less English, start school with significantly lower reading and math scores than the English monolingual students, and are unable to close those gaps by the end of fifth grade. The mixed bilingual children, who also have lower average initial scores than the English monolingual children in Han's study, however, do gain sufficient math learning by the end of fifth grade to draw fully even with the English monolingual group in their achievement. Early language background is an especially important factor in looking at achievement for disadvantaged children of immigrant parents. Of particular importance to this investigation is the finding by Bumgarner, Martin, and Brooks-Gunn (2013), in another study of Hispanic children's achievement, that children who are slow to learn English during the early school years are at particular risk of difficulties in math achievement.

Children of immigrant parents: Development of executive functions and bilingualism

Because EF development and children's achievement both have strong relationships with each other and with early language abilities, there has been significant interest in the EF skills of the children of immigrant parents. As an example, bilingual children in a small experimental setting exhibit stronger attentional control and inhibitory control than monolingual children (Bialystock and Martin, 2004). As the core executive function that begins to emerge very early in childhood, inhibitory control is necessary for tasks that also require both working memory and cognitive flexibility, so this finding is important in considering the outcomes of children of immigrant parents, and has spurred additional examination of IC and bilingualism over time. In a study of bilingual Spanish-speaking and monolingual English-speaking kindergarten children, Carlson and Meltzoff (2008) find that specifically, bilingual children have advantages on tasks involving "conflicting attentional demands." Results from investigation of the abilities of slightly older children (ages 8 to 11) similarly demonstrate that bilingualism is associated with stronger EFs as measured on a variety of tasks; in particular, stronger performance is seen by bilingual children on a task (Flanker) designed to test "interference control," also referred to as the ability to withstand distraction by "misleading alternatives" (Sorge, Toplak, and Bialystok, 2017).

Unsurprisingly, the implications of potential compensatory effects of bilingualism on low-income children's EF skills have been studied increasingly in recent years. In analysis using ECLS-K:2011 data for children from kindergarten through first grade, Hartanto, Toh, and Yang (2019) find that bilingualism moderates the effects of low socioeconomic status on EFs (particularly shifting and inhibition) and self-regulatory abilities. Two studies focusing on bilingualism in children while participating in HS programs separate children into English monolinguals, Spanish-English bilinguals, and Spanish-dominant-emerging bilinguals (or "emerging bilinguals"). One finds that children who are fully bilingual at the start of Head Start participation outperform English monolinguals and emerging bilinguals on measures of inhibitory control (IC) and exhibit steeper growth than English monolinguals during the program on this measure, while emerging bilinguals have the lowest measures of IC at the start of their time in HS, but exhibit faster IC growth than the other two groups during the program (Santillán and Khurana, 2016). Similarly, the second study finds that the fully bilingual group outperforms the other two groups on a unitary latent EF measure; the emerging bilingual group performs at an intermediate level between the other two groups, with monolingual children exhibiting the lowest EF skills (White and Greenfield, 2017).

Purpose of This Paper

While some research has measured outcomes of children of immigrant parents who attend the program, no study has been undertaken to quantify growth trajectories of executive functions, of this subgroup as part of a discussion about the program's overall, long-term ECE benefits. This paper will extend the analyses of paper #2 by analyzing whether growth rates in math, reading, and EFs of children of immigrant parents who attend Head Start vary significantly in comparison to the those of participants with non-immigrant parents, during either kindergarten or the subsequent first and second grade period. Secondarily, I will examine associations between exposure to kindergarten math content and growth curves for the children of immigrant parents who attend HS, in an effort to reveal any differential associations for this important subgroup.

Data and Methods

Analytic sample

From the cohort of the ECLS-K:2011 study produced by the National Center for Educational Statistics (NCES), I employ the full analytic sample for HS children only, with interactive terms as needed with the indicator for "child of immigrant parent." As in the first paper, these are children who were first-time kindergarteners in the fall of 2010 and for whom there is non-missing information on age, gender, race/ethnicity, and parent survey information on early care arrangements in the year before kindergarten[9]. Students were also selected on the basis of non-missing information for the first wave on all four outcomes. This paper draws from survey data, including interview responses conducted with parents and teachers, and direct assessments of the children's EFs and cognitive abilities in both fall and spring each year from kindergarten entry through the spring of second grade, with special reference to the type of care they received in the year before starting school as recorded in parent survey data collected during the fall and spring kindergarten waves. Students were designated as the "children of immigrant parents" based on a variable I constructed that reads "1" if either parent was born in a country other than the United States. The reference category is "children of non-immigrant parents" (i.e.

[9] In accordance with NCES reporting rules, all sample sizes were rounded to the nearest 50 children.

both parents born in US, or single parent born in US). Early care arrangements were designated through the same procedures used in paper #1.

Since previous study of children's EFs and academic achievement shows disparate growth rates for kindergarten and subsequent time periods (Votruba-Drzal, Li-Grining, and Maldonado-Carreño, 2008; Ready and Reid, 2019), I use models employing a multilevel piece-wise growth curve framework, enabling separate estimation for growth rates that describe development during a) the kindergarten year and b) the subsequent two-year period, until the end of second grade. In the multilevel framework, each child's outcomes over time (as defined by the waves when they were assessed) are nested within each child, and children are nested within schools that they attend, as in paper #2.

Missing data was accounted for through multiple imputation, as in paper #1 and #2, but including variables needed to account for school and teacher characteristics. Additional school and teacher characteristics had rates of missing data ranging from 5.7% for highest teacher education level to 13.7% for the total percentage of English Language Learners in each school's student population. In order to retain the analytic sample of Head Start participants (approximately 1,950 children), I estimated missing data with multiple imputation using chained equations, implementing predictive mean matching as needed, to create ten complete datasets with imputed values for the missing covariate predictors, including the indicator for immigrant parents. (As part of the imputation modelling, variables were extensively tested using recommended diagnostics (Eddings and Marchenko, 2012)). In the analysis of outcomes, coefficients and standard errors were estimated for each imputed dataset and combined these using standard procedures to adjust for uncertainty within and between imputations (Rubin, 1976; Rubin, 1987).

Outcome measures

As in paper #2, this paper's focus is on how children's outcomes change over time; its analyses investigate growth rates over time instead of relative growth across groups. Therefore, instead of standardizing outcomes as I did for paper #1, I use measures recommended by the NCES for this type of analysis, as further detailed below (Tourangeau, Nord, Wallner-Allen, Vaden-Kiernan, Blaker, Najarian, Mulligan, 2017; Ready and Reid, 2019).

Executive functions

In this paper I continued using the formal assessments of children's cognitive flexibility (rating children's performance on the Dimensional Card Change Sort task) and working memory skills (measured using the Numbers Reversed task) (Tourangeau, Nord, Wallner-Allen, Vaden-Kiernan, Blaker, Najarian, Mulligan, 2017). In kindergarten and first grade (waves 1 through 4), children's cognitive flexibility was measured by a table-top version of the Dimensional Card Change Sort task (Zelazo, 2006). In second grade, a computerized version of the task was implemented, and so there are no measures of this outcome for the fifth and sixth waves compatible for the estimation of growth across time with the earlier, non-computerized measures. For this outcome only, I am able to include only four waves in my analysis.

Measures provided by the ECLS-K:2011 for children's performance on the first four waves of this task include a pre-switch score (representing only the number of cards correctly sorted by color), a post-switch score (representing the number of cards correctly sorted by shape), a border score (representing the number of cards correctly sorted by the presence or absence of a border on the card), and a combined score each representing the total number of correct responses for the three previous scores. Because most children have proceeded to the Border task by the end of first grade, and following Ready and Reid (2019) in other longitudinal work with this outcome, I used the combined score in its raw metric for each of the four non-computerized waves; these scores are measured by correct responses and range from 0 to 18.

As in paper #1, children's working memory was measured by a backward digit span task across all six tasks, the Numbers Reversed task of the Woodcock-Johnson III Test of Cognitive Abilities (Woodcock, McGrew, and Mather, 2001). For each assessment, children were asked to repeat in correct reverse order a series of numbers read aloud to them, beginning with five series of two-digit numbers, and increasing through progressively larger series of numbers, until they either answered three consecutive series incorrectly or finished responding to the series of eight-digit numbers, at which point the assessment stops.

The ECLS-K:2011 provides five scores in measurement of children's performance on this task including, an age standard score, a grade standard score, an age percentile score, a grade percentile score, and a W-ability score (based on the application of a Rausch model) that represents both a child's ability and the difficulty of tasks measured. For cross-sectional analyses, the NCES recommends the use of one of the first four scores (Tourangeau, et al., 2017). The W-ability score, on the other hand, is useful for the measurement of growth in longitudinal studies. It is based on a common interval scale, such that an increase of a certain number points always represents the same amount of growth, anywhere on the scale. Rather than standardizing scores (with m=0, SD=1) as I did in paper #1, I use the W-ability score on this measure across six waves for all analyses. These scores range from 393 to 693.

Reading and math skills

ECLS-K staff administered IRT assessments in both reading and math beginning in the fall of kindergarten and continuing through all six waves, and I used the scale scores at all time points for the analytic sample. These assessments provide ideal for measures for a longitudinal analysis, since they are measured on a consistent metric reflecting growth over time (Singer and Willett, 2003). Reading IRT scores range from 0-120 and math IRT scores range from 0-113.

Math content level:

Following Engel, Claessens, and Finch (2013) and Engel, Claessens, Watts, and Farkas (2016), I created four numeric "content measures" from data from teacher surveys (from wave 2). Each content measure variable ranges from 0 to 20 and represents the number of lessons on material from that content level per month. They were calculated from teachers' responses to surveys in the spring of kindergarten, when teachers were asked how often each month they taught certain mathematical topics. Earlier studies of math content operationalized the teachers' answers as variables representing the number of lessons each month on which kindergarteners were taught material from each of four content levels, listed here in increasing difficulty and labelled by the authors: "Basic counting and shapes," "Patterns and measurement," "Place value and currency," and "Addition and subtraction." For a listing of specific survey measures comprising each content measure, as well as how variables for each content level were coded using teachers' responses, see Appendix A in paper #2. Following the published work on math content, I also included a control for how many minutes of math instruction in total students received per month (ranging from 0 to 900). In contrast to these earlier papers, which did not model growth curves, I did not standardize the variables for math content but instead used the raw metric math content level variables in estimation for separate groups of children as defined by early care types. Results therefore should be interpreted as associations with *additional lessons*, rather than with a standard deviation increase of time on a particular math content level.

Child and family predictors:

The ECLS-K provided rich measures of the characteristics of children and families, including measures of disadvantage that affect children's early cognitive abilities. These included each child's gender, race/ethnicity, and an indicator of low birthweight. Family characteristics included maternal employment, maternal education, the mother's age at the first birth of her child, an indicator variable for the self-reporting of poor maternal health, whether the family was living either below the poverty threshold, near poverty (between 100% and 199% of the threshold), or above poverty (200% or above the threshold), U.S. region, an indicator for single-parent families, an indicator for having a parent born outside of the U.S., and one for a non-English home language. I also included three indicators for receipt of social aid programs, since these can be predictive of children's cognitive outcomes: current participation in the WIC nutritional program, participation in the last twelve months in the SNAP (food stamp) program, and participation in the last twelve months in the TANF (cash transfer) program. I included an indicator measuring "1" if the child was assessed in Spanish in the first wave of kindergarten.[10] In order to adjust for children's relative maturity and testing experience, each child's age at the time of assessment is included in all analyses; each model includes an indicator reading "1" for the month of each child's first assessment in the fall of kindergarten, since children who are assessed earlier in the fall generally attain significantly lower scores than children who are tested after they have had time to acclimate to their school environment.

School level predictors, teacher characteristics

Models here also include measures that control for aspects of children's school experiences, including an indicator for full-day kindergarten, urban location of school, private school, percentage of school's student body that are English Language Learners (ELL), and the percentage of school's student body eligible for free or reduced lunch and school enrollment.

[10] Fewer than 2% of the total analytic sample required assessment in Spanish in the first wave; the number of children assessed in this way diminished rapidly and dramatically in subsequent waves.

Teachers' years of experience and their educational attainment level (either Less than Bachelor's, Bachelor's Degree, Master's or Professional Degree) were also included as controls.

Analytic approach:

Throughout data collection for the ECLS-K:2011, as students were assessed in fall and spring of each year, it was not possible to assess all of them in the same month of each round; fortunately the month of each assessment was reliably recorded along with the score of each child's assessment. To account for the variation in the amount of time between assessments for each student, I created variables measuring the number of months between assessments, which were then used in separate estimation of monthly growth for two distinct time periods. This approach, a piece-wise growth-curve framework (Singer and Willett, 2003), enabled estimation of separate trajectories of monthly growth rates during a) the kindergarten year, in which EFs develop especially rapidly for most disadvantaged children, and b) the period including first and second grade, for working memory, or the period including first grade, for cognitive flexibility. Other work tracing the effects of specific kindergarten experiences on children's outcomes has employed a similar framework (Votruba-Drzal, Li-Grining, Maldonado-Carreño, 2008; Ready and Reid, 2019) to investigate discrepancies between growth rates during the kindergarten year from those in subsequent years. It is a useful tool for the examination of convergence of outcomes subsequent to early interventions. Each child's scores are nested within their individual learning trajectory, comprised of their initial status at kindergarten entry, their growth rate during kindergarten, and their monthly growth rate during first and second grade (first grade only for cognitive flexibility); the children are then nested within schools.

In order to first compare the rates at which the outcomes of the two subgroups of HS participants, grouped by parent nativity, develop in their earliest school years, I first fit a set of models including time periods, care groups, and interactions of each time period with an indicator for parent nativity. Subsequent modelling for associations of growth rates with math content levels included both math content variables and interactions of each math content level with parent nativity.

The models in simplified form follow here:

First-level (or measurement level):

$Y_{tij} = \pi_{0ij} + \pi_{1ij}TIME1 + \pi_{2ij}TIME2 + \epsilon_{tij}$

Child-level:

$\pi_{0ij} = \beta_{00j} + \beta_{01j}(I_{ij}) + \beta_{02j}(M_{ij}) + \beta_{03j}(F_{ij}) + \beta_{04j}(X_{ij}) + \beta_{05j}(M_{ij}) + r_{ij}$

$\pi_{1ij} = \beta_{10j} + \beta_{11j}(I_{ij}) + \beta_{12j}(M_{ij}) + \beta_{13j}(F_{ij}) + \beta_{14j}(X_{ij}) + \beta_{15j}(M_{ij}) + r_{ij}$

$\pi_{2ij} = \beta_{20j} + \beta_{21j}(I_{ij}) + \beta_{22j}(M_{ij}) + \beta_{23j}(F_{ij}) + \beta_{24j}(X_{ij}) + \beta_{25j}(M_{ij}) + r_{ij}$

School-level:

$\beta_{00j} = \gamma_{000} + \gamma_{001}S_j + u_{ooj}$

$\beta_{10j} = \gamma_{100} + \gamma_{001}S_j + u_{10j}$

$\beta_{20j} = \gamma_{200} + \gamma_{001}S_j + u_{20j}$

Y_{tij} is the growth of child i at time t in school j modeled as a function of the initial level of growth at school entry for child i (π_{0ij}), their monthly growth rate between fall and spring of kindergarten (π_{1ij}), and their monthly growth between spring of kindergarten and spring of second grade(π_{2ij}). (The variables TIME1 and TIME2 provide the number of months between assessments for each child.) Additionally, π_{0ij} is the initial score of child ij at the start of kindergarten, β_{00j} is the mean initial status at the school; I_{ij} represents a dichotomous indicator of whether the child has at least one immigrant parent; M_{ij} represents a dummy for the month of the child's first assessment in fall of kindergarten; F_{ij} represents an indicator of whether the child attended full-time kindergarten; X_{ij} represents a vector of child and family characteristics; M_{ij} represents the set of variables describing math instructional content; $r_{ij}$is the random effect associated with the kindergarten learning rate for child i at school j. As indicated above, β_{00j} is the mean initial status of the outcome at school j. β_{10j} is the average kindergarten monthly learning rate in the school. γ_{000} is the school-average mean initial status for the sample. $S_j$represents a vector of school characteristics included in the model; u_{ooj} represents the initial status error associated with school j; γ_{100} is the mean school-average kindergarten learning rate for the sample.

Findings

Descriptives

Table 1 provides descriptive statistics for comparison across two subgroups of the HS participants (n≈1,900) in my original analytic sample from the ECLS-K:2011 cohort, including means for child, family, teacher, and school characteristics included in models here, as well as the group means for four kindergarten math content levels as well as children's outcomes at each wave. The HS participants are divided by parent nativity, so that the first subgroup of children (n≈1,300) have parents who were born in the U.S., while the second subgroup (n≈650) is comprised of children who have at least one parent who was born outside of the U.S. This proportion is slightly larger than the 27% of children with immigrant parents in the cohort overall (Sullivan, Houri, and Sadeh, 2016).

In paper #1, we saw that HS participants are on average the most disadvantaged group of children among groups organized by early care type. Among HS participants, the children of immigrant parents exhibit even greater disadvantages on some important measures than the children of non-immigrant parents. More than half of the families with at least one immigrant parent report living below the poverty level (51.4%), a significantly higher proportion than that of HS families with only non-immigrant parents (43.9%, $p<.001$). Critically for children's early cognitive outcomes, a much higher proportion of their mothers have less than a high school education (30.5%) in comparison to the mothers of the children with non-immigrant parents (14.2%, $p<.001$). More of the mothers in the immigrant families are not employed and not seeking work (39.9%) than their counterparts (23.4%, $p<.001$). Levels of benefit receipt vary between the two groups vary in unexpected ways, and will be discussed further. An advantage for children of immigrant parents is that far fewer of them (16.5%) live in single-parent families than their counterparts with non-immigrant parents (42.8%).

Unsurprisingly, a much higher proportion of children in this group live in households in which English is not the primary language (61.9%), in contrast to households with non-immigrant parents (4.6%, $p<.001$). Country or region of origin are not included in this study, although importantly, many of the immigrant parents likely immigrated from Spanish-speaking countries, since 64.1% of the children with at least one immigrant parent are Hispanic, in comparison to just 17.5% ($p<.001$) of children of non-immigrant parents. Black (non-Hispanic) children made up just 8.4% of the HS participants with at least one immigrant parent, while 31.4% ($p<.001$) of HS participants with non-immigrant parents were black. Similarly, just 8.1% of the HS participants with at least one immigrant parent were white (non-Hispanic), in comparison to 43.2% ($p<.001$) of those with native parents. In contrast to percentages of white and black HS participants, however, approximately 14.9% of HS participants with immigrant parents are Asian, in comparison with only 10% ($p<.001$) of children with non-immigrant parents who are Asian.

Nonetheless, the subgroup of HS participants with at least one immigrant parent is almost 2/3 Hispanic, and this is an important consideration, in part because many immigrants – an untraceable proportion – from Central America and Mexico are likely undocumented immigrants; while the ECLS-K:2011 did not request information from parents about their immigration status because of privacy concerns, it is considered likely (Sullivan, Houri, and Sadeh, 2016) that both documented and undocumented immigrants' children form part of the sample. The undocumented status of some immigrant parents may somewhat explain both the greater level of financial adversity in this subgroup, and it almost certainly accounts for lower average reports of benefit receipt among the immigrant parents in comparison to non-immigrant parents. Among parents of HS participants who are non-immigrant, 15.7% report welfare receipt in the past year, compared to just 9.1% ($p<.01$) of parents living in a household with at least one immigrant parent; similarly, 58.6% of non-immigrant parents report food stamp receipt in the same period, in contrast to 41.5% ($p<.001$) of parents in a household with at least one immigrant parent. These disparities in take-up of benefits may be rooted in self-protective behavior common to undocumented parents, regardless of their level of need, because they are afraid of discovery by authorities (Yoshikawa, 2011). While proportions of parents who report current WIC receipt on the ECLS-K survey are roughly the same between the subgroups (80.2% for non-immigrant parents in comparison to 79.5% of those for families with at least one immigrant parent), this is also a part of a pattern among undocumented parents, since WIC program benefits can be more easily identified exclusively as responses to the needs of *children*, and not their parents. Receipt of WIC benefits is higher rates for other programs among immigrant families because underprivileged U.S. citizen offspring, if not their parents, are legitimately entitled to them (Yoshikawa, ibid.).

The two groups of HS participants differ significantly in the characteristics of their schools and teachers as well, with a much higher proportion of children of immigrant parents attending schools in urban areas (41.1%, compared to 26.8% for children of non-immigrant parents). Children of immigrant parents, unsurprisingly, attend schools with higher average proportions of English Language Learners (ELL) (30.4%) compared to schools that children with non-immigrant parents attend (12.3%, $p<.005$). Both subgroups are likely to attend schools with a high proportion of students eligible to receive free or reduced price lunches (64.4% for children of non-immigrant parents and 69.3% for children of at least one immigrant parent). A slightly higher proportion of the teachers of children from non-immigrant families have Bachelor's degrees (53.9%, compared to 49.6% of teachers of children of immigrant parents), while the reverse is true of teachers with a Master's or advanced degree. They form a majority (50.1%) of teachers of HS participants from families with at least one immigrant parent, and 45.8% of teachers of HS participants from non-immigrant families.

According to second-wave teacher surveys, differences exist between the subgroups' mathematics instruction, HS participants from families with at least one immigrant parent receive fewer minutes (367) of kindergarten math instruction per month, on average, in comparison to HS participants of non-immigrant parents (380, $p<.001$). Teachers report that the children of immigrant parents receive slightly greater numbers of lessons in basic mathematics content (12.2 lessons/month in "Basic counting and shapes" in comparison with 11.4 ($p<.001$) for children of native parents; and 8.18 lessons/month in "Patterns and measurement" in comparison with 7.56 (p.<001) for children of non-immigrant parents). They receive slightly fewer lessons, on average, in “Place value and currency” (9.99 lessons/month in comparison with 10.5 ($p<.01$) for children from non-immigrant families), but somewhat more frequent lessons for “Addition and subtraction” (9.68 lessons/month in comparison with 9.12 ($p<.01$) lessons/month for children of non-immigrant families).

Analysis

Comparison of growth rates

Note on interpreting results: As measures in this paper were not standardized (in contrast to paper #1), coefficient estimates in the Tables of this paper refer to actual points of student assessments. Where they describe growth curves, coefficients refer to a *monthly* growth rate within a time period, either during kindergarten or during the period between the spring of kindergarten and the spring of second grade. To describe associations involving math content levels is to describe the relationship between an outcome (in points) and a single lesson relating to the content level each month.

Tables 2 and 3 provide growth rates for four outcomes across the two HS subgroups, unadjusted for math content levels or other controls or predictors. During kindergarten, the average growth rates of HS participants with non-immigrant parents and those with at least one immigrant parent are not significantly different on either Numbers Reversed (measuring working memory for this cohort) or the DCCS task (measuring cognitive flexibility). However, among the children from immigrant households, there is a significantly higher growth rate for both EF measures in the *second* time period. In paper #2, we saw all growth curves flatten for all children to relatively indistinguishable rates from one another (as defined by care groups) in the second period, which lasts from the spring of kindergarten to the spring of second grade for working memory outcomes and from the spring of kindergarten to the spring of first grade for cognitive flexibility. Here, there is a significant burst of growth in EF development for the children of immigrants *after* the typically high-growth period of kindergarten; the rates for this group on Numbers Reversed are higher, at 1.59 points per month in contrast to the rate for HS participants with non-immigrant parents (1.36, $p<.001$). This rate across the first and second grade period represents a sizable steady increase at a time characterized by slower growth in working memory for most children. Similarly, the subgroup of children with immigrant parents also grows more during the second period (only first grade for this outcome) in their cognitive flexibility, at a rate of .093 points per month in comparison to .059 ($p<.05$) points per month for the children of non-immigrant parents. Additionally, as noted in paper #2, for working memory this second period includes two summers (between kindergarten and first grade and between first and second grades), times when disadvantaged children usually lack opportunities for continued cognitive stimulation (Waldfogel, 2012). Were these summers not included in the overall period for first and second grades, it is possible that the monthly growth rates for the working memory of children of immigrant parents, critically, would be even larger.

Monthly growth rates for HS participants in math, presented in Table 3, indicate more similar achievement for the two subgroups in math and reading during both periods. Seen in terms of growth rates, there are small positive differences for the children of immigrant parents across both math and reading scores that are not statistically significant, with one marginal exception. Growth rates in reading for children of immigrant parents are 2.48 points per month during kindergarten, in comparison with those of children of non-immigrant parents (2.31, $p<.10$). Especially given the slightly lower initial scores of the children of immigrant parents, this suggests that perhaps efforts by schools to boost early language skills for such children (often including ELL instruction or DLL classes) may provide important gains during kindergarten that are exhibited here as early improvements in reading scores. Improved language abilities developed during kindergarten, so critically beneficial for this subgroup, may in turn help set the stage for the unusually high subsequent growth patterns in EFs among children from immigrant families (from Table 2), as well as supporting increasing, steady achievement in math.

Interactive models: exposure to math content levels

At this point my research question shifts from overall differences in trajectories to associations of growth rates with exposure to kindergarten math content levels, as interacted with parent nativity and time periods. Subsequent models in Tables 4 through 7 each present growth curves for the full group of Head Start participants. Rather than comparing the subgroups side by side, I included interactive terms in order to investigate how coefficients vary for HS participants from immigrant families. The analysis of each outcome otherwise is consistent in form with those in paper #2, so that the first model (1) estimates “fixed effects” for the four levels of math content as well as the growth curves on each outcome for “Period 1” (kindergarten) and “Period 2” (end of kindergarten through end of second grade); this model also includes interactive terms to determine whether there is a separate and significant “fixed effect” for children of immigrant parents, and an additional significant term for each growth rate for these children as well. Estimation is then refined in model (2) by interactions of each math content level with each of the periods; additional interactions for this paper include each math content level with *both* each period *and* being the child of immigrant parents. Then follows a “fully adjusted” model (3) that additionally includes an extensive range of child, family, school, and teacher characteristics for each student. Here I discuss findings for each outcome separately, with particular focus on findings specific to differences for children with immigrant parents, and in cases comparisons to findings from paper #2.

Numbers Reversed:

In the first, simplified model in Table 4, a difference emerges for children of immigrant parents, consistent with findings from Table 2. For an interactive term of the growth curve for time period of first and second grades (Period 2 Intercept X Immigrant parents), there is a highly significant coefficient of moderate size (.236, p<.001), representing increased growth in working memory for these children. When added to the Period 2 intercept of 1.35 (p<.001) for the HS group as a whole, this suggests a growth rate of 1.59 points per month during first and second grade (a 17% increase for children of immigrant parents). This is significantly larger than growth rates for the same period of any ECE groups in paper #2 (Table 2), and it corresponds with the growth rate for this subgroup in Table 2 of this paper.

Interestingly, the coefficient for this interactive term is both smaller (.166) and insignificant in model (2), suggesting that the additions of interactions for specific types of math content for each period with parents' immigrant status in this model may account for the surge of growth in working memory for children of immigrant parents in the second period. Associations for lessons in specific math content levels with either group's growth in working memory are *not* significant, however. It could be that other factors experienced during kindergarten, while associated with lessons in math content, do account for the surge in working memory growth among children of immigrant parents. As the interactive term for growth in the second period and immigrant parents becomes insignificant for models (2) and (3), however, the coefficient of the growth rate for the second periods (which applies to both subgroups of children) become larger than that in model (1) (1.45, p<.001 in model (2), and 1.46, p<.001 in model (30)). The growth rate for period 1, also for both subgroups, decreases slightly (2.67, p<.001 for both models (1) and (2)).

What is also of interest here is a comparison with Table 4 from paper #2, in which there were no interactions for parent nativity but a marginally significant, negative "fixed effect" on working memory outcomes associated with lessons on "Basic counting and shapes," (-.339, p<.10). As soon as growth curves for children of immigrant parents are introduced in model (1) of this paper's Table 4, the coefficient for "Basic counting and shapes," is non-significant, though still negative (-282). In model (2) of this paper, with the addition of terms to account for disparate associations of math content by parent nativity, the "fixed effect" for "Basic counting and shapes" is larger and resumes its marginally significance (-.501, p<.10); while the addition in model (3) of controls causes it to diminish and become non-significant once again, suggesting that variation in children's backgrounds, families, teachers and schools make such lessons of highly variable worth to children.

DCCS:

Findings in Table 5 for DCCS scores are similar to those for Numbers Reversed, in that the first model demonstrates an unusual surge of growth in the development of cognitive flexibility among the children of immigrant parents during the *second* period, in the first grade; this coefficient (.034, p<.05), if added to the intercept for the entire HS group (1.35, p<.001), suggests a 57% increase to a growth rate of .093 points per month during this one-year period. Again, this rate significantly outpaces estimates of growth rates in cognitive flexibility of any care group during this period in paper #2, and it is consistent with the rate in Table 2 in this paper seen for the children of immigrant parents.

Once again, the coefficient for this interactive term is insignificant in model (2), suggesting that the additions of interactions for specific types of math content for each period and the indicator for parent nativity (in model 2) may account for that surge. There is only one slight, marginally significant coefficient, for lessons in “Place value and currency” with growth during first and second grades, but it is negative (-.003, p<.10). As modeled here, math content level instruction does not account for higher growth in first and second grades for children of immigrant parents, although differences associated with how such instruction varies across the subgroups may account for these positive differences.

As the differential coefficients for the interactions of immigrant parents with the second period become insignificant in model (2), as with the Numbers Reversed outcome, there is an increase period 2 growth rate, which now applies to both subgroups in first and second grade, although it is less significant, implying more variation in the full group (.064, p<.05).

Math IRT:

Models in Table 6 do not demonstrate significant differences in the associations of exposure to math content with growth rates according to parents’ immigrant status, although associations with advanced math content, critical to paper #2, remain significant and apply to both subgroups. Patterns similar to those in paper #2 are present, with a small positive “fixed effect” of lessons in “Place value and currency” (.142, p<.10) in model (1), and the positive associations of kindergarten growth rates with lessons in “Place value and currency” (.021, p<05 in models 2 and 3) and “Addition and subtraction” (.017, p<05 in models 2 and 3).

That associations with math content and growth curves are similar for all HS participants is generally unsurprising; after all, as the growth rates in Table 3 suggest, the rates of learning are not significantly different in math between the two subgroups for there to be important differences in the way they react to math content levels.

Reading IRT:

Models in Table 7, which include variation by math content levels by subgroup for each time period, do not reflect the marginally higher growth rates seen in Table 3 for the children of immigrant parents during kindergarten (2.48 points per month, $p<.10$) in comparison to the rate of children's of non-immigrant parents rate (2.31 points per month). In models (2) and (3) of Table 7, however, the association of lessons on "Place value and accuracy" is slightly larger than it was in similar models in paper #2 (before variation by parent nativity was taken into account). The coefficient here, which applies to both subgroups, is .021, $p<.05$ during kindergarten. It is interesting that this effect increases in these models, especially since the nonsignificant interactive effect for "Place value and currency" with Period 2 and parents' nativity is negative (-.010), making it unlikely that such lessons provided even more benefit to the reading outcomes of children of immigrant parents. Nonetheless, it is fortunate that the positive association of these lessons with growth rates in reading for so many children appears consistent for the children of immigrant parents who attended HS.

Discussion

1) Without consideration of math content levels, do growth curves for the subgroups defined by parent nativity differ for working memory, cognitive flexibility, math or reading?

In comparison with HS participants of non-immigrant parents, those with immigrant parents appear to experience an additional period of high growth in both EF measures during the second period. This is particularly important in the case of Numbers Reversed assessments, since working memory is strongly associated with achievement for children as they move through elementary school (Duncan and Nguyen, 2019). It is also interesting given recent investigations into stronger average EF skills for fully bilingual and even emerging bilingual children. Paper #2 presents evidence suggesting that HS participants as a group demonstrate significantly higher growth rates in working memory than more advantaged children during kindergarten, while their growth in first and second grades slows to become much like most all other children in the full analytic sample, regardless of their early care type. Here, we see evidence suggesting that children of immigrant parents continue on a significantly steeper trajectory in their working memory development in comparison with their peers with non-immigrant parents, exhibiting a monthly growth rate of 1.59 ($p<.001$) points per month for first and second grades, in comparison to 1.36 for children of non-immigrant parents. The extension of growth is rarely seen in trajectories for this period of children's development, although Reardon and Galindo (2009) do illustrate similar ones for the math achievement through fifth grade for first-generation Hispanic immigrant children.

In paper #1, we saw that Head Start participants experience a small gain in their cognitive flexibility (as measured by their performance on the DCCS task) in comparison to children who received no center-based care in the year preceding kindergarten. In Table 2 of this paper, we see that growth rates on this measure in that first year of school for the two subgroups across parent nativity are indistinguishable from each other. However, at baseline (kindergarten entrance) the HS participants with immigrant parents began with slightly lower scores on this measure when compared to HS participants with non-immigrant parents (1.35 compared to 1.39, $p<.05$). Both groups exhibit the same growth rates during kindergarten. Interestingly, it is not until the first grade period when children of immigrant parents demonstrate dramatically higher growth rates on their cognitive flexibility assessments during first grade (.093 compared to .059, $p<.05$ for their counterparts with non-immigrant parents).

Bilingualism's relationship with inhibitory control and shifting *may* support this unusual trajectory, although it is not clear in this work how many children in the subgroup of children of immigrant parents are fully bilingual. While the extension of the positive trajectory in this area for these children is intriguing, it is not clear why their divergence in EF growth rates from the children of native parents occurs relatively late in their trajectories here. It is important to note that both differences in the second period represent growth in EF measures in comparison with not just the children of non-immigrant parents who attended HS, but in comparison to average gains for children from other care groups (as seen in paper #2), although we do not yet know what the EF growth trajectories for children of immigrant parents look like within those other groups.

As seen in Table 3, growth rates in math do not vary statistically by parent nativity among HS participants during these early school years. In contrast, children of immigrant parents have slightly faster growth rates in reading during kindergarten, a difference which is marginally significant (2.48 compared to 2.31 for children of non-immigrant parents, $p<.10$). So alongside evidence of extended gains in working memory and cognitive flexibility for the children of immigrant parents, achievement in the first and second grade period in math and reading does not follow a similar pattern. While there is a “trend” in some coefficients indicating that on average, the academic achievement of the children of immigrant parents slightly outpaces that of the children of non-immigrant parents, the non-significance or marginal significance of coefficients suggests that higher growth in EFs in the second period simply does not translate into academic achievement for this sample of children of immigrant parents – or, at any rate, does not do so by the end of second grade. This is consistent with an observation from the study of outcomes at kindergarten entrance, from paper #1, noting that children of parents of lower educational levels seem to “get less” out of their EF development in terms of academic growth than children with parents of higher educational levels, since we know that mothers of children of immigrants are on average less highly educated than mothers of children of non-immigrants.

Another possibility is that the children of immigrant parents are too diverse, even within the strongly disadvantaged HS participants, for there to be clearer results here. We know, for example, that the average achievement of children of Asian immigrant parents (14% of this subgroup of children of immigrant parents) tends on average to outpace the average achievement of children of Hispanic immigrant parents (66% of the children of immigrant parents subgroup) (Han, Lee, and Waldfogel 2012).

2) Does exposure to either or more basic or advanced math content have different associations with the growth rates in math of HS participants, depending on parent nativity?

Results in Table 6 show no major differences in associations of math content levels to growth rates for HS participants with immigrant parents in comparison to participants with non-immigrant parents. However, the significant and positive association of lessons in both "Place value and currency" (.021, $p<.05$) and "Addition and subtraction" (.017, $p<.05$) with monthly growth rates in math achievement during kindergarten applies to both subgroups of HS participants.

3) Does exposure to either more basic or advanced math content have different associations with the growth rates in reading for HS participants who have immigrant parents?

Similarly, Table 7 demonstrates no significant differences between HS participants across the two subgroups, children of immigrant parents and children of non-immigrant parents, in terms of their reading achievement in association with exposure to math content levels. The association of lessons on "Place value and currency" to monthly growth rates in math achievement during kindergarten (.021, $p<.05$) applies to all HS participants, regardless of parent nativity.

4) Do associations of any level of math content with growth rates in EF measures vary for

HS participants by parent nativity?

Models in Tables 4 and 5 demonstrate no significant differences across the subgroups for parent nativity in associations of math content level with growth in either working memory or cognitive flexibility between children of immigrant parents and children of non-immigrant parents.

***

In summary, analyses across subgroups of HS participants by parent nativity suggest that within this disadvantaged group, the children of immigrant parents experience extended positive trajectories in their EF skills after entering school, into first grade on cognitive flexibility and even second grade on working memory, past the initial growth in kindergarten exhibited by the HS group as a whole. It is not clear, however, that variation in exposure to kindergarten math content levels, as measured in lessons per month, holds any explanation for these differences or for differences in math or reading achievement. Coefficients are not significant for interactions involving math content levels or parent nativity.

Literature on bilingualism and executive functions suggests that children of immigrant parents who do not grow up speaking exclusively English may exhibit development in this area that is stronger than that of monolingual children. Bilingual or emerging bilingual children appear to hold early advantages in inhibitory control and even latent EF, according to recent studies of disadvantaged children (Santillán and Khurana, 2016; White and Greenfield, 2017). This could in some way explain the unusual pattern of growth for these measures, based on a greater likelihood of exposure to more than one language for many children of immigrant parents. In this context, however, it is somewhat surprising that baseline EF levels of children of immigrant parents, in comparison to children of non-immigrant parents, are significantly lower on cognitive flexibility and statistically indistinguishable on working memory for HS participants (Table 3). It creates questions about effects of the program as it specifically engages children of immigrants, before school entry. Here, it could be that school experiences in kindergarten after HS, for many children of immigrant parents, stimulate the advantages in growth that they go on to exhibit. Ultimately, however, it is important that this additional growth does not emerge, at this stage, in math and reading growth rates for children of immigrant parents as it does for their EF growth rates.

As noted, the significance of coefficients indicating extended growth in the second period for the EF development of children of immigrant parents disappears when interactions with group and math content are added. At the same time, the interactions of parent nativity with exposure to math content levels are not significant in these later models, making this an unsatisfying explanation for differences in EF development. Instead of seeing emerging significance for math content levels with growth rates in working memory in these models, one notes that with the addition of interactions with math content levels, the kindergarten growth rate for both subgroups decreases by 20%, and the first and second grade growth rate for both groups increases by 7.4%, averaging trajectories across both subgroups. One explanation for this is that potential variation of associations for growth rates with math content levels interacted with immigrant parent nativity is too large, particularly given the relatively small number (approximately 650) of children of immigrant parents in the sample.

Relative to the entire ECLS-K:2011 cohort, the children of immigrant parents who attended HS programs are relatively disadvantaged. However, the literature on children of immigrant parents emphasizes how misleading averages can be for this diverse subgroup. The effects of interventional measures for such children, even in a high-poverty subsample, could vary considerably. There are important differences in this group by parent country of origin, for example, and 14% of children of immigrant parents are Asian, who typically exhibit higher achievement levels in comparison to other subgroups. Important differences also result from children's proficiency at English, as well as in which wave they become sufficiently proficient to be assessed in English. As a check, I attempted models with interactions including indicators for children having been tested in Spanish at wave one (period X math content level X parent nativity X indicator for Spanish assessment), and results did not clarify associations with math content levels, perhaps owing to smaller and smaller subsample numbers involved in estimation of these already-complex models.

In conclusion, the steeper average trajectories in EFs of children of immigrant parents in the initial models suggest that this study involves elements of the "immigrant paradox," wherein these especially challenged children manage to outpace their peers on at least some measures. Since we know that the children of immigrants in this study attend schools, on average, with higher percentages of ELL students, and Ready and Reid (2019) presents evidence suggesting that such higher rates are associated with lower early EF growth, this is yet another example of how surprising the strong growth rates are for this group. Recent work suggests, there are advantages in inhibitory control, particularly at the low end of the SES distribution, for children who are bilingual or even emerging bilinguals, but other research does not find that such advantages reliably extend to working memory skills, specifically "verbal" memory skills as measured by the Numbers Reversed task (Hartanto, Toh, and Yang, 2019). An additional paradox, then, is that we do see extended growth on the Numbers Reversed task for the group of children with immigrant parents, who presumably have somewhat higher levels of bilingualism.

Limitations

There could be more satisfying results on the question of whether exposure to math content levels can affect the children of immigrant parents differently than those of non-immigrant parents. As an example, one might design a study differently, perhaps employing more variables relating to language (the proficiency of mothers in English, for example), the nativity and countries of origin for both parents, and critical data on each child's home learning environment (all of which are available in the ECLS-K:2011). It is also quite possible that what is truly effective in boosting the outcomes of the children of immigrant parents stems from other resources, such as ELL instruction, and that there are no significant differences for math content level by parent nativity. Particularly the finding here on extended gains for working memory suggests that it might be helpful to continue examination of achievement for this subgroup of children of immigrant parents, perhaps as far as fifth grade, and with more attention to their language background and proficiency; possibly it would be illustrative to compare results, once more, for children of immigrant parents within other groups as defined by early care types, and not just Head Start. As Bumgarner, Martin, and Brooks-Gunn (2013) demonstrate, it is possible for a non-academic measure that generally predicts higher achievement (Approaches to Learning, in this study) to drive effects in *later* time periods, since growth across domains is not necessarily concurrent in children's development, and curricula make very different demands on children's capacities in different grades.

Tables

Table 3. 1**:** Descriptive Statistics of Head Start Participants by Parents' Immigration Status

Parent nativity	**Non-Immigrant** (n≈1,300)	**Immigrant** (**n**≈650)
Child characteristics		
Gender		
Female	.472	.459***
Male	.528	.541***
Race/ethnicity		
White (non-Hispanic)	.432	.081***
Black (non-Hispanic)	.314	.084***
Hispanic	.175	.641***
Asian (non-Hispanic)	.010	.149***
Other (non-Hispanic)	.069	.044**
Birthweight		
Normal birthweight	.878	.910***
Low birthweight (< 2500 g)	.122	.091**
Diagnosed disability (parent report)	.227	.135***
Maternal characteristics		
Age at child's birth (years)	21.0	22.4
Education		
Less than high school	.142	.305***
High school graduate	.310	.306
Some college or technical	.431	.240***
College graduate	.117	.148**
Employment status		
Full-time	.436	.315***
Part-time	.205	.198
Looking for work	.126	.088**
Not working	.234	.399***
Mother's health = poor (self-rated)	.148	.163*
Family characteristics		
Single parent household	.428	.165
Number of siblings	2.55	2.64
Poverty status		
Above 200% of poverty level	.283	.220**
Near poverty level	.278	.266*
Below poverty level	.439	.514***
Benefit receipt		
WIC receipt (current)	.802	.795
Welfare receipt (# months in past year)	.157	.091**

Table 3. 1: Descriptive Statistics of Head Start Participants by Parents' Immigration Status

Parent nativity	**Non-Immigrant** (n≈1,300)	**Immigrant** (**n**≈650)
Food stamps receipt (# months in past year)	.586	.415***
Non-English is primary household language	.046	.619***
Child assessed in Spanish in Wave 1	.012	.042**
Family lives in urban area	.726	.893***
Region of residence		
Northeast	.140	.146+
Midwest	.244	.141***
South	.442	.262***
West	.173	.451***
School characteristics and experiences		
Full-day kindergarten	.904	.843***
Public school	.951	.960**
School enrolment	483	598***
School in urban area	.268	.411***
Percentage of ELL students	12.3	30.4***
Percentage receiving free/reduced price lunch	64.4	69.3***
Teachers' years of experience	14.3	13.9*
Teacher qualifications		
Less than a bachelor's degree	.003	.003
Bachelor's degree	.539	.496***
Master's or advanced degree	.458	.501***
Mathematics instruction in kindergarten		
Time on math in class (minutes/month)	380	367***
Mathematics content level		
Basic counting and shapes	11.4	12.2***
Patterns and measurement	7.56	8.18***
Place value and currency	10.5	9.99**
Addition and subtraction	9.12	9.68**
Outcomes		
Continuous EF Measures		
Numbers Reversed (fall kindergarten)	427	423***
Numbers Reversed (spring kindergarten)	444	440***
Numbers Reversed (fall 1st grade)	453	450***
Numbers Reversed (spring 1st grade)	465	463***
Numbers Reversed (fall 2nd grade)	469	471***
Numbers Reversed (spring 2nd grade)	477	477
DCCS "W" score (fall kindergarten)	14.3	13.5***
DCCS "W" score (spring kindergarten)	15.1	14.6***
DCCS "W" score (fall 1st grade)	15.7	15.5***

Table 3. 1**:** Descriptive Statistics of Head Start Participants by Parents' Immigration Status

Parent nativity	**Non-Immigrant** (n≈1,300)	**Immigrant** (**n**≈650)
DCCS "W" score (spring 1st grade)	15.8	15.7***
Cognitive IRT Scores		
Math (fall kindergarten)	28.3	28.1***
Math (spring kindergarten)	41.7	41.8***
Math (fall 1st grade)	49.0	49.7***
Math (spring 1st grade)	62.3	62.0***
Math (fall 2nd grade)	67.3	67.7***
Math (spring 2nd grade)	76.6	78.1***
Reading (fall kindergarten)	44.3	43.6***
Reading (spring kindergarten)	58.1	57.5***
Reading (fall 1st grade)	63.7	65.4***
Reading (spring 1st grade)	80.1	80.0**
Reading (fall 2nd grade)	85.4	85.6***
Reading (spring 2nd grade)	92.9	93.1***

Subsample sizes are rounded, in accordance with NCES guidelines, to the nearest 50 students. Subsamples rounded per NCES guidelines to nearest 50 students.
*** p<.001 ** p<.01 * p<.05 + p<.10

Table 3. 2: Monthly Growth Rates for Head Start participants' executive functions by Parent Nativity, from fall of kindergarten through spring of second grade

	Numbers Reversed		DCCS	
Parents' Nativity	Non-Immigrant (n≈1,300)	Immigrant (n≈650)	Non-Immigrant (n≈1,300)	Immigrant (n≈650)
Initial level (fall K)	432	428	13.9	13.5*
Monthly growth: fall to spring kindergarten	3.13	3.04	.184	.183
Monthly growth: spring kindergarten through spring 2nd grade (spring 1st grade for DCCS)	1.36	1.59***	.059	.093*

Subsamples rounded per NCES guidelines to nearest 50 students.
*** p<.001 ** p<.01 * p<.05 + p<.10
Monthly growth rates in points-gained-per-month. Adjusted for month of child's assessment in fall of kindergarten.

Table 3. 3: Monthly Growth Rates for Head Start participants' math and reading by Parent Nativity, from fall of kindergarten through spring of second grade

	Math IRT		Reading IRT	
Parents' Nativity	Non-Immigrant (n≈1,300)	Immigrant (n≈650)	Non-Immigrant (n≈1,300)	Immigrant (n≈650)
Initial level (fall K)	31.1	30.7	47.4	46.6
Monthly growth: fall to spring kindergarten	2.30	2.35	2.31	2.48+
Monthly growth: spring kindergarten through spring 2nd grade (spring 1st grade for DCCS)	1.47	1.51	1.52	1.52

Subsamples rounded per NCES guidelines to nearest 50 students.
*** p<.001 ** p<.01 * p<.05 + p<.10
Monthly growth rates in points-gained-per-month. Adjusted for month of child's assessment in fall of kindergarten.

Table 3. 4: Monthly growth rates in Numbers Reversed for HS participants by parental nativity: effects for kindergarten math content levels

	Lessons per month math content levels (1)	With interactions: math content levels with time periods (2)	Fully adjusted: child, family, school and teacher characteristics (3)
Immigrant parents	-1.78	-.844	-1.58
Lessons/month on math content:			
Basic counting and shapes	-.282	-.501+	-.262
Patterns and measurement	-.255	-.042	.109
Place value and currency	.110	.194	.103
Addition and subtraction	.190	.115	.113
Immigrant parents: interactions with math content			
Immigrant parents x Basic counting and shapes	-.014	-.113	-.204
Immigrant parents x Patterns and measurement	.170	-.265	-.199
Immigrant parents x Place value and currency	-.209	.005	.010
Immigrant parents x Addition and subtraction	-.076	.017	.094
Period 1: fall to spring kindergarten			
Intercept	3.13***	2.67***	2.67***
Period 1 X Basic counting and shapes		.032	.039
Period 1 X Patterns and measurement		-.058	-.057
Period 1 X Place value and currency		.022	.023
Period 1 X Addition and subtraction		.034	.035
Immigrant parents X Period 1	-.102	-.112	-.066
Period 1 X Immigrant parents X Basic counting and shapes		.022	.024
Period 1 X Immigrant parents X Patterns and measurement		.078	.072
Period 1 X Immigrant parents X Place value and currency		-.013	-.029
Period 1 X Immigrant parents X Addition and subtraction		-.006	-.065
Period 2: spring kindergarten through spring 2nd grade (thru spring 1st grade for DCCS)			
Intercept	1.35***	1.45***	1.46***
Period 2 X Basic counting and shapes		-.006	.006
Period 2 X Patterns and measurement		.004	.003
Period 2 X Place value and currency		-.013	-.014

Table 3. 4: Monthly growth rates in Numbers Reversed for HS participants by parental nativity: effects for kindergarten math content levels

	Lessons per month math content levels (1)	With interactions: math content levels with time periods (2)	Fully adjusted: child, family, school and teacher characteristics (3)
Period 2 X Addition and subtraction		-.006	-.006
Immigrant parents x Period 2	.236***	.166	.155
Period 2 X Immigrant parents X Basic counting and shapes		-.001	-.001
Period 2 X Immigrant parents X Patterns and measurement		.006	.007
Period 2 X Immigrant parents X Place value and currency		-.007	-.006
Period 2 X Immigrant parents X Addition and subtraction		.009	.008

Subsamples rounded per NCES guidelines to nearest 50 students.
*** p<.001 ** p<.01 * p<.05 + p<.10
Monthly growth rates in points-gained-per-month. All models adjusted for month of child's assessment in fall of kindergarten.

Table 3. 5: Monthly growth rates in DCCS scores for HS participants by parental nativity: effects for kindergarten math content levels

	Lessons per month math content levels (1)	With interactions: math content levels with time periods (2)	Fully adjusted: child, family, school and teacher characteristics (3)
Immigrant parents	-.225	-.441	-.447
Lessons/month on math content:			
Basic counting and shapes	-.021	-.005	.013
Patterns and measurement	-.008	-.029	-.021
Place value and currency	.025	.024	.015
Addition and subtraction	.001	.004	.003
Immigrant parents: interactions with math content			
Immigrant parents x Basic counting and shapes	-.016	.017	.010
Immigrant parents x Patterns and measurement	.017	.027	.031
Immigrant parents x Place value and currency	-.011	-.029	-.030
Immigrant parents x Addition and subtraction	-.004	-.015	-.016
Period 1: fall to spring kindergarten			
Intercept	.181***	.182**	.178**
Period 1 X Basic counting and shapes		-.004	-.004
Period 1 X Patterns and measurement		.002	.002
Period 1 X Place value and currency		.004	.004
Period 1 X Addition and subtraction		.004	-.001
Immigrant parents X Period 1	.002	.036	.054
Period 1 X Immigrant parents X Basic counting and shapes		-.001	-.001
Period 1 X Immigrant parents X Patterns and measurement		-.002	-.002
Period 1 X Immigrant parents X Place value and currency		-.001	-.001
Period 1 X Immigrant parents X Addition and subtraction		-.002	-.001
Period 2: spring kindergarten through spring 2nd grade (thru spring 1st grade for DCCS)			
Intercept	.059***	.064*	.064*
Period 2 X Basic counting and shapes		.001	.001
Period 2 X Patterns and measurement		.002	.001
Period 2 X Place value and currency		-.003+	-.003+
Period 2 X Addition and subtraction		.001	.001
Immigrant parents x Period 2	.034*	.036	.034

Table 3. 5: Monthly growth rates in DCCS scores for HS participants by parental nativity: effects for kindergarten math content levels

	Lessons per month math content levels (1)	With interactions: math content levels with time periods (2)	Fully adjusted: child, family, school and teacher characteristics (3)
Period 2 X Immigrant parents X Basic counting and shapes		-.006	-.006
Period 2 X Immigrant parents X Patterns and measurement		-.001	-.001
Period 2 X Immigrant parents X Place value and currency		.003	.004
Period 2 X Immigrant parents X Addition and subtraction		.009	.003

Subsamples rounded per NCES guidelines to nearest 50 students.
*** p<.001 ** p<.01 * p<.05 + p<.10
Monthly growth rates in points-gained-per-month. All models adjusted for month of child's assessment in fall of kindergarten.

Table 3. 6: Monthly growth rates in Math IRT scores for HS participants by parental nativity: effects for kindergarten math content levels

	Lessons per month math content levels (1)	With interactions: math content levels with time periods (2)	Fully adjusted: child, family, school and teacher characteristics (3)
Immigrant parents	.941	.880	1.14
Lessons/month on math content:			
Basic counting and shapes	-.083	-.081	.078
Patterns and measurement	-.110	-.108	-.095
Place value and currency	.142+	.125	.071
Addition and subtraction	.087	.072	.075
Immigrant parents: interactions with math content			
Immigrant parents x Basic counting and shapes	.032	.044	.008
Immigrant parents x Patterns and measurement	-.023	-.048	-.002
Immigrant parents x Place value and currency	-.075	-.063	-.096
Immigrant parents x Addition and subtraction	-.069	-.070	-.063
Period 1: fall to spring kindergarten			
Intercept	.2.29***	2.05**	2.05***
Period 1 X Basic counting and shapes		-.011	-.012
Period 1 X Patterns and measurement		-.001	-.001
Period 1 X Place value and currency		.021*	.021*
Period 1 X Addition and subtraction		.017*	.017*
Immigrant parents X Period 1	.056	.089	.085
Period 1 X Immigrant parents X Basic counting and shapes		-.009	-.008
Period 1 X Immigrant parents X Patterns and measurement		.025	.025
Period 1 X Immigrant parents X Place value and currency		-.015	-.015
Period 1 X Immigrant parents X Addition and subtraction		.002	.001
Period 2: spring kindergarten through spring 2nd grade (thru spring 1st grade for DCCS)			
Intercept	1.47***	1.61***	1.61***
Period 2 X Basic counting and shapes		-.004	.006
Period 2 X Patterns and measurement		.001	.003
Period 2 X Place value and currency		-.005+	-.014
Period 2 X Addition and subtraction		-.005*	-.006

Table 3. 6: Monthly growth rates in Math IRT scores for HS participants by parental nativity: effects for kindergarten math content levels

	Lessons per month math content levels (1)	With interactions: math content levels with time periods (2)	Fully adjusted: child, family, school and teacher characteristics (3)
Immigrant parents x Period 2	.046	.017	.016
Period 2 X Immigrant parents X Basic counting and shapes		.004	.004
Period 2 X Immigrant parents X Patterns and measurement		-.003	-.003
Period 2 X Immigrant parents X Place value and currency		.001	.001
Period 2 X Immigrant parents X Addition and subtraction		.001	.001

Subsamples rounded per NCES guidelines to nearest 50 students.
*** p<.001 ** p<.01 * p<.05 + p<.10
Monthly growth rates in points-gained-per-month. All models adjusted for month of child's assessment in fall of kindergarten.

Table 3. 7: Monthly growth rates in Reading IRT scores for HS participants by parental nativity: effects for kindergarten math content levels

	Lessons per month math content levels (1)	With interactions: math content levels with time periods (2)	Fully adjusted: child, family, school and teacher characteristics (3)
Immigrant parents	.781	.966	.632
Lessons/month on math content:			
Basic counting and shapes	-.117	-.076	.051
Patterns and measurement	-.046	-.049	-.038
Place value and currency	.074	-.084	.043
Addition and subtraction	.057	.064	.062
Immigrant parents: interactions with math content			
Immigrant parents x Basic counting and shapes	-.086	-.081	-.103
Immigrant parents x Patterns and measurement	-.035	-.060	-.025
Immigrant parents x Place value and currency	.033	.026	-.019
Immigrant parents x Addition and subtraction	-.047	-.052	-.049
Period 1: fall to spring kindergarten			
Intercept	.2.31***	2.07***	2.07***
Period 1 X Basic counting and shapes		.002	-.001
Period 1 X Patterns and measurement		-.004	-.003
Period 1 X Place value and currency		.021*	.021*
Period 1 X Addition and subtraction		.003	.003
Immigrant parents X Period 1	.170	.473	.472
Period 1 X Immigrant parents X Basic counting and shapes		-.008	-.007
Period 1 X Immigrant parents X Patterns and measurement		.013	-.013
Period 1 X Immigrant parents X Place value and currency		-.010	-.010
Period 1 X Immigrant parents X Addition and subtraction		.002	.001
Period 2: spring kindergarten through spring 2nd grade (thru spring 1st grade for DCCS)			
Intercept	1.52***	1.68***	1.68***
Period 2 X Basic counting and shapes		-.010+	-.010+
Period 2 X Patterns and measurement		.001	.001
Period 2 X Place value and currency		-.004	-.004
Period 2 X Addition and subtraction		-.002	-.002
Immigrant parents x Period 2	.001	-.094	-.094

Table 3. 7: Monthly growth rates in Reading IRT scores for HS participants by parental nativity: effects for kindergarten math content levels

	Lessons per month math content levels (1)	With interactions: math content levels with time periods (2)	Fully adjusted: child, family, school and teacher characteristics (3)
Period 2 X Immigrant parents X Basic counting and shapes		-.001	-.001
Period 2 X Immigrant parents X Patterns and measurement		.007	.008
Period 2 X Immigrant parents X Place value and currency		.003	.003
Period 2 X Immigrant parents X Addition and subtraction		.001	.002

Subsamples rounded per NCES guidelines to nearest 50 students.
*** p<.001 ** p<.01 * p<.05 + p<.10
Monthly growth rates in points-gained-per-month. All models adjusted for month of child's assessment in fall of kindergarten.

IX. Conclusion

Using matching methods to compare participants to similar children in four groups who experienced different primary care arrangements in the year before kindergarten, paper #1 provides evidence suggesting that in comparisons with children who received either exclusive parental care or informal care by relatives and non-relatives, there are small positive effects for Head Start (HS) participants in their cognitive flexibility, as well as small gains in reading and math scores. Children who participate in HS demonstrate working memory skills that are not significantly different from those of children who experience no center-based care, but their skills in this area are slightly weaker than those of children who attended school-based public pre-k or other center-based care. On teacher assessments in comparisons with children who experienced only parental care, HS participants exhibit fewer internalizing behaviors but more externalizing behaviors, and no differences on Approach to Learning (ATL) measures. In comparison with children cared for informally by relatives and non-relatives, HS participants exhibited lower inhibitory control and higher measures of externalizing.

The slight but significant gains in reading and math for HS participants in comparison to children who experienced no center-based care are interesting in light of the statistically similar levels of average working memory for all of these groups of children. Schager et al. (2013) suggest that HS analyses involving outcomes that are not closely tied to HS curriculum (they cite vocabulary and IQ as examples) typically do not demonstrate positive effects, so perhaps it is not surprising that HS does not produce gains on this outcome. Yet since working memory is the EF most strongly associated with children's achievement (Nguyen and Duncan, 2019), it becomes even more important to investigate whether the slight advantages in academic subjects conferred by the program persist beyond kindergarten entrance.

In additional consideration of the results from paper #1, it was not possible with the ECLS-K:2011 data to examine variation in the characteristics of HS programs (teacher certifications, curricula, etc.) to better understand these findings. However, we do know that, in contrast to most pubic pre-k programs, most HS programs follow a "whole child" curriculum rather than a skills-specific curriculum designed to boost students in particular cognitive areas, such as literacy or math (Jenkins and Duncan, 2017). This is consistent with the program's original design, which was intended to support children across multiple domains, but this approach may also account for the relative slightness of gains in reading and math, as well as the lack of any positive gain in working memory in comparison with any group.

Paper #2 uses ECLS-K:2011 data using piece-wise linear growth curves to analyze children's development in working memory, cognitive flexibility, reading and math, using the care type group framework, but with focus on Head Start participants. Generally, during kindergarten we expect average cognitive growth for disadvantaged children to exceed growth rates for more advantaged children on most measures. The findings for HS participants here suggest that, with other less advantaged groups of children, they do experience a period of high growth rates in working memory, cognitive flexibility, and reading during kindergarten (followed by a slowing, or flattening, to similar rates across most groups in first and second grades). However, growth rates in math for HS participants in this important year for "catch up" are not statistically different from those of more advantaged children who attended pre-k or other center-based care, meaning that they are slower than those of other disadvantaged children. This result is particularly significant in the context of the especially low initial average levels of math scores for HS participants at the start of kindergarten entrance (-.349 SD), and of course the lack of positive HS effect on working memory outcomes.

The analysis of kindergarten exposure to math content levels suggests that advanced math content in kindergarten does have a positive relationship with math and reading achievement for Head Start participants, but that this group of students does not gain as much on average from this instructional approach as some others do. More basic math content, such as counting, has no association with the math achievement of Head Start children as a group, although it does have a negative association with growth in math for more advantaged groups of children. Lessons in basic math content may provide very slight gains in working memory growth rates to certain groups of less advantaged children, although they appear to have marginally significant, negative "fixed effect" associations for growth in this outcome among HS participants. Lessons in more advanced math content have a few negative associations for working memory development in specific periods for some groups of children, usually for growth rates in first and second grade. Finally, any gains in kindergarten growth rates resulting from math content do not persist through first and second grades.

It is interesting that for several groups of students, including HS participants, advanced math content, specifically lessons in "Place value and currency," has a positive and significant association with children's *reading* growth rates in kindergarten, and it is not attenuated with any significant negative finding in the subsequent period (as associations with growth rates in math typically are). This suggests that appropriately aligned instruction in kindergarten math content levels have the potential to improve outcomes other than math.

An overriding concern is that for HS students, their growth rates in math continue to be depressed, regardless of their kindergarten exposure to math content levels, basic or advanced. For the most disadvantaged students, a low-cost intervention is insufficient.

Taken together, these paper's findings on HS students suggest that early assessment of math skills may be critical for them, before the determination of appropriate curriculum. Further, they suggest that for many HS participants, there may be real need of immediate math remediation.

In terms of how instructional practices are studied in the transitional period, it is striking that while we can detect patterns in the ECLS-K:2011 cohort as a whole, they may not always be helpful in assessing associations or effects for students most in need of intervention. Additionally, in a study like this, we remain unsure if we are seeing the associations for math content lessons or for something else that was happening in similar ways at the same time for certain groups of students in the study.

Paper #3 investigates growth rates in math, reading, cognitive flexibility and working memory for HS participants, comparing rates for children of immigrants with rates of children of non-immigrants, as well as whether associations between exposure to math content level in kindergarten and children's growth curves for these two periods differ across these groups. Results indicate that HS participants with immigrant parents exhibit an additional surge in EF development in the period between the spring of kindergarten and the spring of second grade, *later* than the average kindergarten increase for all HS participants. Additionally, HS participants with immigrant parents exhibit slightly higher average growth rates in reading during kindergarten when compared to HS participants with non-immigrant parents. I find no significant differences indicating that the outcomes of HS children of immigrants are differentially related to exposure to levels of math content during kindergarten. However, advanced math content in kindergarten has slight positive relationships with math and reading achievement for Head Start participants that hold steady across children with immigrant parents and children with non-immigrant parents. The persistent positive growth in EF development in the children of immigrant parents, extending into first and second grade, is a hopeful sign, possibly suggesting that their eventual academic achievement could accelerate in future years. In conclusion, the steeper average trajectories for the EFs of children of immigrant parents suggest that this study involves elements of the “immigrant paradox,” wherein these especially challenged children manage to outpace their peers on at least some measures. On the other hand, they remain quite disadvantaged in comparison with most U.S. schoolchildren.

Limitations

Paper #1 is the only one of these papers that addresses selection bias, by close matching of HS participants with children from each of the other care types, using a wide range of characteristics that predict both the selection of HS and young children’s cognitive outcomes. Even so, if for example an unmeasured child or family characteristic were to violate the assumption of ignorability, it could mean that estimates here are biased. For example, if maternal IQ (which is not available in ECLS-K data) is far more closely predictive of children’s early EF skills than the maternal education measure that is provided, and the groups compared are not well-matched on maternal IQ, HS effects on working memory or cognitive flexibility could be inaccurately represented here.

For papers #2 and #3, which provide comparisons of growth rates for all children in each group *without* countering selection bias, this problem is likely more serious. We do not have information about *why* certain children participated in Head Start rather than another form of early care, nor about why they attended a certain elementary school, and so to ascribe differences in outcomes purely to either ECE or to school experiences (such as math content level) is problematic. One child’s parent may have had no choice in selecting Head Start because of where they live, while another parent may have chosen it over a less enriching (or more enriching) type of care, for a variety of reasons that also reflect important family characteristics. Likewise, how children are selected into particular types of schools (and even some classrooms) tends to reflect family characteristics that are predictive of outcomes. Nonetheless, these two papers provide clear data on the respective growth rates of disparate groups as defined by early care group, with some indication that a curricular choice like math content level does affect learning during specific time periods – and differentially among the subgroups.

Another major limitation of each of the papers is a lack of detailed information on the early care environment. Factors such as hours attended, certification and quality of teachers, caregiver stability, curricula, and classroom attributes can significantly affect the effectiveness of ECE programs, and the lack of specificity here is unfortunate. As an example, if many or most HS participants attended the program for less than twenty hours per week, this may mean that positive effects are underestimated here, especially since we know that for some groups of children, more hours of attendance is critical to improved academic outcomes (Lee, Han, Waldfogel, and Brooks-Gunn, 2018).

Implications for Policy and Practice

Findings in paper #1 and the follow-up analyses of trajectories for HS children through second grade support a shift in curriculum for HS, as it supports four-year-olds in particular, to a format that more specifically "primes" children for academic work in school. Increases at kindergarten entrance in reading and math scores of HS participants in comparison to closely matched children who did not attend center-based care were slight, and their working memory performance at this point in time was low enough on average to predict serious learning challenges for the HS group. Additionally, that we do not see a surge in growth rates in math outcomes for HS participants comparable to those for other disadvantaged groups, once they arrive in kindergarten (as presented in paper #2), suggests that their prospects for educational success are quite compromised. A move to "Pre-K For All" with appropriate curricula for four-year-olds as HS programs shift focus to three-year-olds may be a useful way to approach this challenge in some areas; as yet, however, local availability of pre-k does not yet extend throughout as many U.S. communities as it needs to, for many families and their children. There may be the need to adjust HS curricula in a more centralized policy position.

Secondly, results from all papers support more early assessment and intervention at school entry, for math remediation and in order to address other special, early needs of disadvantaged students. While to a certain extent here the evidence on exposure to math content levels in kindergarten is inconclusive, since we do not know whether significant findings result from a sufficiently high (or low) number of lessons in a particular topic, indications are clear that a) in general, lessons in advanced math content are associated with improved outcomes for more children than not, and b) results nonetheless vary across children. Some children get more benefit than others from advanced math content, while others get none at all. Some actually benefit from additional lessons in basic content, and not always on the outcomes we expect. For disadvantaged students in general, it would be imprudent to rely *only* on a low-cost, broad intervention, such as shifting to more advanced math content, as a way of boosting their outcomes in the transitional period of kindergarten. (Of course, that is not what the researchers of math content level were advocating, but it is important to stress.)

The results in paper #3 suggests that for HS participants who are the children of immigrants, it may be important to balance their needs as ELL students with interventional work aimed at bolstering early math learning and possibly, working memory skills. Focus in Bailey, Duncan, Odgers and Yu (2017) on the *timeliness* of interventions could be critical in addressing the needs of students with atypical trajectories. Simply making educators aware, across settings in both HS centers and schools serving disadvantaged children of immigrants, of the learning profiles and vulnerabilities of such children, could be critically helpful. It is suggested that advantages in inhibitory control and self-regulation, possibly arising from bilingualism, could mask the need for critical support in building skills more clearly predictive of achievement.

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